THE EFFECTS OF SALMON FISHERIES ON SOUTHERN RESIDENT KILLER WHALES

PROCEEDINGS FROM WORKSHOP 1: PARTICIPANT DISCUSSION AND FEEDBACK

Prepared for

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INTRODUCTION

In early 2011, the National Marine Fisheries Service (NOAA Fisheries) and Fisheries and Oceans Canada (DFO) convened a bilateral scientific workshop process to evaluate the effects of salmon fisheries on Southern Resident Killer Whales. The central question of this process is: "To what extent are salmon fisheries affecting recovery of Southern Resident Killer Whales by reducing the abundance of their available prey, and what are the consequences to their survival and recovery?" The major components of the process include three workshops and a report by an independent scientific panel.

On September 21-23, the first of the three workshops was held in Seattle, WA, with the following objectives:

1. Establish and discuss the factual context: what do we know about threats to Southern Resident killer whales, their feeding habits, and the relationship between salmon abundance and killer whale population dynamics?
2. Present and discuss analyses done to date, including work by NOAA Fisheries scientists (especially for consultations on the 2008 PST Agreement and 2011 Puget Sound Resource Management Plan), work by DFO scientists, and work by other scientists.
3. Identify and discuss key assumptions and uncertainties. Explore the potential for reducing uncertainties with additional information and/or alternative methods in the short term (i.e., prior to Workshop 2) to improve confidence in the results and address questions. Identify any other short or long term research that may contribute to reducing uncertainties.
4. Identify and assign specific follow-up tasks for completion and presentation at Workshop 2.

Approximately 100 invitees attended this workshop, including presenters, science panel members, and other participants. Collectively, these scientists and researchers brought together extensive expertise on the biology, ecology and population dynamics of Killer Whales and Pacific Salmon populations; the management of salmon fisheries in Alaska, British Columbia, and Washington; and statistical techniques for analyzing the potential relationships among these factors.

Scientists from NOAA, DFO, state agencies, and universities presented over 30 talks (see Agenda, Appendix 1). An critical component of the workshop structure was to allow as much time as possible for questions and discussion of the material presented – to clarify understandings of the analyses performed, to offer alternative hypotheses, to recommend improvements to analytical approaches, to evaluate the quality of evidence presented, and to serve overall as an informal peer review of the research presented. The workshop steering committee considered questions and feedback from the Science Panel, other presenters and other participants to all be extremely important to the overall process. Accordingly, we only gave the Science Panel priority for up to half of the duration of each discussion period. Given the size and interest of the audience we knew that there would be insufficient discussion time for everyone to participate in the discussion. Therefore, we provided a feedback template to all participants to facilitate the collection of feedback following the workshop.

This document includes all of the feedback received from participants for each presentation and/or session from the workshop. It represents a compilation of all of the submissions received from participants following the workshop, supplemented with questions and comments raised during the workshop. For each review submitted, the reviewer is identified by name and affiliation, and their comments or recommendations are reported exactly as received. For issues raised during the workshop, the commentators are not identified and their points have been paraphrased. The summary of comments by workshop participants is in note form only. NOAA-Fisheries recorded the entire workshop, so a more detailed record is available.

This document does not include the questions, comments, responses, and recommendations of the Science Panel, either during or after the workshop. The contributions of the Science Panel are compiled in a separate document.

The participant feedback and discussion contained within this document are organized by workshop presentation in the same order as the actual workshop. For each presentation, the feedback submitted following the workshop is presented first, organized by reviewer, and then followed by the questions and comments from the actual workshop. The questions and comments from the discussion periods that followed a particular set of presentations at the workshop are presented following the same set of presentations in this document. At the end of the document are several reviews submitted by participants responding to multiple topics or complext topics that span multiple presentations. The legend below provides further guidance to the structure of the document.

<u>Document Legend</u>

WORKSHOP SESSION

Presenter(s)

Presentation title

Reviewer, Affiliation

<u>Question being addressed</u>

Comments, feedback, responses, etc., submitted following the workshop. Submissions are recorded exactly as submitted.

Questions and Issues Raised at the Workshop

- *Questions, comments, responses, etc. from the brief question period following each presentation at the workshop. Comments are recorded in relatively raw, note form.*

Discussion on Set of Presentations

- *Questions, comments, responses, etc. from the longer discussion period following a set of presentations at the workshop. Comments are recorded in relatively raw, note form.*

1. WELCOME

NO COMMENTS

2. SETTING THE CONTEXT

John Ford, DFO

Current status and trends of resident killer whales (current & historical abundance, trends, differences between Northern & Southern Residents)

John H. Clark, ADFG

Suitability of methods used for the problem

A very informative talk. However, additional information concerning SRKW and NRKW would have been very useful to the workshop. Page 18 of the presentation provides abundance data for the SRKW and NRKW populations. Neither here nor elsewhere in the following presentations during the workshop was information provided concerning number of breeding females in the two populations through the period of 1970-2011, yet that information is available and would be most useful. Further statistics including calves per breeding age female through the time series would also be useful.

Throughout the workshop, presenters referred to decreasing abundance, yet the data demonstrates that NRKW are increasing with a slight dip in the late 90’s and SRKW abundance has likewise increased through the time-frame, but at a lower rate. Most attendees I talked with find it difficult to accept the notion that these populations are in trouble given that abundance has increased over the 40 years wherein population level information is readily available.

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

The most important analysis that should be prepared prior to the next workshop is a coupling of the abundance data already provided with available information concerning sex and age of the two populations. Trends in females of breeding age should be provided. Trends in calves produced per breeding age female should be provided. Detailed information concerning mortality of killer whales should be provided including the annual distribution of these mortalities since 1970, the breakdown of the composition of the mortalities by age and sex, and the distribution of mortality by age and sex in differing parts of the year.

A thorough presentation of such information coupled with meaningful analysis would greatly assist the Panel and other participants to be able to hone in on whether or not there is a problem and if so, where and when the problem occurs rather than being asked to basically buy off on the concept that food defined as adequate numbers of Chinook has or will limit the two killer whale populations.

Robert Conrad, NWIFC

Other comments / Other studies or references that would be helpful to the Science Panel

A leading hypothesis is that the slow growth of the SRKW population is related to limited prey (primarily “large” Chinook salmon) abundance|availability. Four possible contributors to the reduced abundance|availability are:

1. A decrease in overall Chinook abundance|availability because of population declines due to habitat loss and other non-fishing related causes.
2. Competition with other increasing populations of marine mammals such as seals and sea lions.
3. Competition with the increasing numbers of the Northern Resident Killer Whales.
4. Reduction in availability due to fisheries.

How do you determine the relative importance of each of these possible contributors to the reduced abundance|availability of Chinook salmon? Can you determine what changes over time for each of these possible contributors coincide with the decreased growth rate of the SRKW population?

Susan Bishop, NOAA

Adequate consideration of uncertainties and confounding variables

Did not answer Bowhay question about why reasonable to assume that AK, northern and southern population growth rates should be comparable.

*Validity and clarity of **conclusions** (logical path from data and analyses to conclusions)*

Ford emphasized effect on productivity from demographic disruptions from live capture or other uneven mortality effects. However, Ward did not find demographic effects was the major parameter effecting reproduction.

Other comments / Other studies or references that would be helpful to the Science Panel

Question asked about importance of winter to mortality. Ford answered that summer period SRKW may be eating above kilo requirements to help in the winter. However, NWFSC staff had said that the summer period would not be more important because the animals were too big and kilo requirements too large per unit time to be able to rely on a specific time period to carry them over. So this appears to be different scientific assessments to important questions.

Tim Tynan, NOAA

Other comments / Other studies or references that would be helpful to the Science Panel

Need to ascertain whether the “removal” data presented by Ford for SRKWs in the 1960s did in fact include estimates of the number of animals that died incidentally during the act of capture. Focus of capture was on young animals, but were key (mature) females/males also "removed" (killed) from the population? If so, adult animals killed incidentally should be taken into account in assessing the ability and expected duration for the population to rebound. and for retrospective analyses of productivity.

Northwest Indian Fisheries Commission

General comments on overview

This was a good overview that introduced several avenues for exploration of factors affecting SRKW population growth (besides possible limitations related to Chinook abundance) that were not pursued much in the rest of the workshop. Specifically,

1. Why do we see very good population growth of the Northern Resident Killer Whales, harbor seals in the Georgia Basin ecosystem, and Stellar Sea Lions in the Georgia basin ecosystem but slower growth for the SRKW? Why doesn't the growth of the SRKW population more closely resemble the growth seen in these other populations which rely at least partially on the same prey base?

2. There was reference to a genetic bottleneck in the SRKW that apparently occurred some time in the distant past (> 100 years ago) that may be limiting SRKW population growth. Why wasn't there more exploration of this factor in the workshop?

3. There were data presented on the removals of individuals from the SRKW population for the aquarium trade in the 1960s and 1970s (35 individuals) and the demographic effects this had on the SRKW population. There was only a brief discussion of the possible effects this may still be having on the growth of the SRKW population. Also, DFO and NOAA seemed to be of different opinions on whether these removals are still impacting the population or not. DFO said might still be, NOAA said probably not.

How do you evaluate and compare the possible effects of these factors on the growth of the SRKW population and contrast and rank them relative to the effects from a possible limitation of Chinook abundance?

We would like to offer two other observations regarding this presentation: 1) That this presentation on the status of SRKW population lacked context without an estimate of current carrying capacity. The current population reflects an abundance level in the upper quadrant of the range of abundance for population that has been observed over the last 4 decades. This doesn't seem to support either agency's contention that this population is at high risk of extinction.

The SRKW population is growing in both overall number and reproductive females, yet both agencies conclude that the population is endangered with extinction? Based on information presented it is not even clear that the population is depleted based on current conditions.

An estimate of current carrying capacity is required to assess the status of this population. Either DFO or NOAA should be requested to present such an estimate of current carrying capacity at the second workshop.

2) The point that the SRKW population exhibits a slow rate of growth, suggesting that it is artificially constrained. These comments were made throughout the workshop in comparison to the growth rates estimated for NRKW population. These comparisons should be considered in light of that these populations are in different ecosystems and subject to entirely different environmental factors. In addition, the NRKW population feed upon several of the same salmon stocks upon which the SRKWs depend. The NRKWs are thriving as are several other marine mammal species (harbor seals, California sea lions, Stellar sea lions) that also feed upon the same chinook stocks that the SRKW rely upon. There was also evidence presented that these other species appear to be at or near their carrying capacity (Jeffries). So why wouldn't you assume SRKWs are as well?

Is it reasonable to assume that the Southern Residents should be growing at a faster rate given these trends with other competitors and that the chinook abundance/returns to the Salish Sea have been stable or modestly increasing in recent years (Parken and Kope)? Either DFO or NOAA should be requested to present modeling results from an ecosystem analysis that includes all of the top predators that target chinook to support their assertions that the SRKW population is depleted and exhibiting a slower growth rate that it should.

Questions and Issues Raised at the Workshop:

- *The reported impact of the live fishery counts both successful captures and mortality experienced in failed capture attempts.*
- *When the matriarch dies, it can trigger fission of group. But not always sure. We can infer relatedness of subsequent groups. Males can breed far outside their matriline, but the bond to return is strong.*
- *If culling of NRKW by fishermen is a factor, then residents should have suffered more. Transients move more, don't linger around fisheries. May have been some dispersal of transients from inshore waters that later returned.*
- *Seals represent a smaller proportion of the prey of transients when represented in terms of calories instead of numbers.*
- *Northern and Southern residents overlap but maintain independence.*
- *The hypothesis about the abundance trend for AB Pod (N. Gulf of Alaska residents) is mortalities among key members and demographic issues.*
- *Is it reasonable that the growth rates of Northern and Southern residents would be similar considering they inhabit different ecosystems? They may have been differentially affected by live-capture. There may be important demographic differences too.*
- *Low reproduction depends heavily on mother, some can reproduce every 3 years. It can be affected by neo-natal mortality, but that is hard to assess as it occurs when we don't see them.*

- *Unsure how this compares to other mammals of similar body mass.*
- *It is important to know where they go in the winter. We're doing our best to expand our knowledge of winter distribution and behavior. Conditions are very difficult and there are very few workable days in small boats. We're trying to establish acoustic detection.*

Lynne Barre, NOAA / Paul Cottrell, DFO

NOAA and DFO Recovery Plans (threats and limiting factors, etc.) and plan implementation

Northwest Indian Fisheries Commission

General comments:

The recovery goals that were presented were measureable, but not meaningful. Not all factors for decline had recovery goals that assured that conditions would be stabilized and improved. Efforts should be taken to address this deficiency.

The one recovery goal related to actual population parameters is too narrowly focused as it only addresses productivity. Recovery goals should be established for the SRKW population that relate to both productivity and abundance. It is doubtful that a population that is at or near its current carrying capacity could achieve the productivity metric presented. The incorporation of a recovery goal expressed as an abundance level or range could address this shortfall.

Our request is that the second workshop includes a presentation by either NOAA or DFO of an analysis based on recent population dynamics of the likelihood that the SRKW population could achieve the current recovery goal.

Questions and Issues Raised at the Workshop:

- *It's important to look at year-round availability of Chinook and other prey, not just abundance.*
- *The number of permits issued between the two countries (under ESA and SARA) are published online and coordinated between national agencies.*

Discussion on Set of Presentations

- *How stable do we think these groups are? How long has SRKW been a unique identifiable group? As a small population with low fecundity, how often would they blink out? Very interesting imponderable. We have discussed this issue. How vulnerable are they? How has this specialization evolved and is it viable? This makes it difficult to assess what "recovery" looks like. We are lacking the longer term data for historical data and carrying capacity. These questions are difficult with long-lived individuals.*
- *The only way to look at KW history is through archaeological or genetic evidence. Most evidence suggests that SRKW have been around 100s of years, probably 1000s, maybe 10,000s*

– they are not blinking out on a human time-scale. In the absence of human perturbation, the chance of extinction should be low.

- *There have been other actions of DFO to reduce Chinook fisheries but those have not been for KW but for Chinook conservation itself.*
- *We suspect winter ecology is very important, but we know so little. If they continue their summer patterns through winter, it's likely they will have prey issues. Maybe they eat above their requirement to last the winter. Mortality seems to mostly occur during fall/winter. Questions regarding nutritional stress in winter seem important.*
- *Knowing body condition in fall/winter would be valuable. Current methods only observe condition at the end of summer. We'd love to know more about winter but are substantially constrained.*
- *Prey availability is a bottom-up control, but top-down control is often very important in such social structures (dominant demographics, changes in density). Not much support for density dependence at this point.*
- *We have the genotypes for about 70-80% of the individuals..*
- *The basis for the specialization is fairly anecdotal from captured whales. Transients wouldn't eat fish when fed. They are able to develop traits to specialize on particular prey. We would like to know more about prey flexibility, because they seem inflexible.*
- *The effect of live capture has diminished. Now female structure seems relatively similar between Northern and Southern residents. There are still differences to some extent but insufficient to have major effects.*
- *The age structure of males and the proportion of males are both quite different between Northern and Southern residents.*
- *Neither DFO or NOAA are aware of fish farmers killing KW.*

3. Current State of the Science on Killer Whale Feeding Habits

John Ford, DFO

Overview of resident killer whale feeding habits

John H. Clark, ADFG

*Suitability of **methods** used for the problem*

A nice overview of diet studies.

Adequate consideration of uncertainties and confounding variables

Page 9 of presentation provides summary of potential biases from fragment sampling approach used to document diet. Fecal sampling has additional biases as do samples taken from whales that died. However, even with the biases, it is pretty clear that SRKW consume large Chinook out of proportion to large Chinook abundance as compared with other salmonids.

*Validity and clarity of **conclusions** (logical path from data and analyses to conclusions)*

This and other work demonstrate RKW **preference** for large Chinook.

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

This presentation and other available information make clear that RKW selectively consume Chinook and in addition select larger Chinook out of proportion to their abundance. Biologically, it makes sense that given a choice, a RKW would prefer larger prey and Chinook are the largest of the Pacific salmon with higher oil content and caloric content.

That they prefer large Chinook is different than that they **NEED** large Chinook. Several presenters used the words **resident killer whale NEEDS** when they incorporate diet results into models and other analyses. While it is readily established that RKW prefer large Chinook, it is not at all clear that RKW populations along the Pacific coast of North America would not survive just fine sans any Chinook salmon as a prey item as is obviously the case for killer whale populations elsewhere in the oceans of the world.

The misinterpretation of RKW dietary results wherein preference is passed over and instead is interpreted as **NEED** lacks scientific validity.

Susan Bishop, NOAA

Adequate consideration of uncertainties and confounding variables

Is prey choice obligate or preferred? Previous presentation Ford said that SRKWs were innovative in adapting to new methods of prey capture, prey switches to chum in fall when Chinook at low abundance. Sockeye in large numbers present at same time and space with Chinook and SRKW in summer. Any indication that SRKW take more sockeye in years of low abundance? If SRKW diet switches prey to chum when preferred prey is very limited in fall, why wouldn't SRKWs switch to available sockeye if truly nutritionally stressed? Is Chinook abundance not low enough to cause switch? Is Chinook abundance not low enough for long enough period of time?

Tim Tynan, NOAA

*Suitability of **methods** used for the problem*

PSC (SJF – Area 20) and DFO (JS – Area 12) purse seine test fishery CPUE data were used as surrogates to indicate Chinook salmon abundance in the marine approach areas relative to other salmon species. Ford should note that the test fisheries are directed at sockeye and pink salmon in July-September, and chum salmon in September-November, using methods and fishing areas that are suitable and selected for assessing the abundances of those species. A20 and A12 test fishery CPUE data are not likely to be adequate measures of relative Chinook salmon abundance due to areal/temporal migrational behavior, gear susceptibility, and other differences between the target species and the non-target Chinook salmon.   Chinook salmon catchability is likely low, considering the gear types and areas fished.

Other comments / Other studies or references that would be helpful to the Science Panel

Ford should consult with the PSC and DFO biologists responsible for managing, and analyzing data from A20 and A12 sockeye, pink, and chum salmon test fisheries to understand why they might not provide good indicators of migrating and resident Chinook abundance.

Northwest Indian Fisheries Commission

General comments on overview

There is definitely strong evidence that large Chinook salmon are a very important element in the diet of SRKW. The preponderance of diet data is based on scales collected from feeding events or fecal samples. The question arises though whether current data collection methods are adequate to provide an unbiased estimate of the proportion of the diet that is being met by Chinook. It appears that there is a large potential for positive bias (over-estimating the contribution of Chinook) when relying upon scale samples collected from surface feeding events because of:

1. Chinook salmon scales are relatively more deciduous than other salmon scales (especially in larger Chinook), therefore, they may be more of them available in the water column after feeding events than scales from other salmon and other fish species.

2. Chinook scales have a relatively larger surface area than scales from other salmon and fish species, therefore, they may be suspended in the water column longer than scales from other species.

3. Larger Chinook are more apt to be brought to the surface to consume/share (provide more samples), than smaller fish.

4. Observations of feeding events at the surface are much fewer than what should be consumed based on bioenergetic estimates of need. They must be eating something not observed or needs are grossly overestimated.

Also, it is interesting to note that the data presented by Ford shows that pink salmon compose a much larger portion of the juvenile SRKW salmonid diet (more than 15%) compared to adults (negligible). This seems to indicate that SRKW do prey on pink salmon when younger so they value them as a food resource when younger and one would think that if food was scarce they would access this resource as adults. But adults are only very rarely seen to prey on pink salmon.

Questions and Issues Raised at the Workshop:

- *Some work has been done on stable isotope analyses for Chinook specialists. Shift in diets geographically, but isotope work is consistent with prey sampling data. Another issue is groundfish, which may not be shared as much as salmonids.*
- *What about the uncertainties in the estimates of salmon abundance? Scale of abundance vs. scale of scale/foraging sampling? How do you get the resolution of forage to match resolution of abundance?*
- *Nutritional stress appears more distributed than expected with sole foragers, potentially due to prey sharing. We expect younger to suffer more, but we don't see that occurring.*

Brad Hanson, NOAA

SRKW diet from prey remains and fecal samples

Northwest Indian Fisheries Commission

General comments:

The results from the fecal sampling are difficult to interpret without knowing (a) if the feces produced by different prey species have a different buoyancy or not, (b) what proportion of bowel evacuations occur at the surface compared to at deeper depths from which samples are never recovered, and (c) what is the SRKW digestive efficiency for its different prey species.

We can't make sense of two slides presented by Hanson; 1 slide (#25) shows that for samples collected in Sept. during the 2004-08 sample years, 16 of 39 fecal samples had coho in them (compared to 14 samples with Chinook). So coho appear to be an important food item in Sept. (as important as Chinook). A later slide based on DNA cloning says that coho only contributed 16% to the diet in Sept. (samples years 2007 and 2008 only).

John H. Clark, ADFG

Adequate consideration of uncertainties and confounding variables

This presentation and the one by Ford and Ellis provide good overviews of the methods used and results obtained by researchers attempting to document food consumed by resident killer whales.

Bits of remaining tissue and scales are collected after observing a feeding whale; such methods are confined to surface waters with potential biases including the likelihood of larger prey items being over-represented in samples, prey items less dense being over-represented (higher lipid content), larger scales being more likely to be over-represented (those from larger fish), etc. Others attempt to collect scat; such methods are likewise confined to surface waters with scat samples that are of lesser density being more likely to be over-represented in collected samples, while scat that is more dense is more likely to sink and not be collected..

In that Chinook are larger than almost any of the other documented species consumed by SRKW and NRKW populations and have a higher lipid content (less dense), it is obvious that methods used will provide results that are biased positively toward Chinook representation in diets of these whales.

At times, the results of tissue/scale based results and fecal based results provide markedly different results. For instance, page 36 of the subject presentation shows Chinook as a trace only prey item for resident killer whales in the month of November, whereas, page 37 of the subject report show fecal based estimates for the same month as Chinook representing about 45% of the diet of resident killer whales.

The results of diet studies are dependent upon the biases inherent in the collection of samples and sample sizes are typically limited in space and time. The limited sample sizes, when then used to garner further insight into stock composition introduces considerable uncertainty.

For instance, page 24 of the subject report provides sample sizes used for genetic analyses of stock composition of Chinook in diets of resident killer whales. From the graphic, May sample size was about 5 Chinook, June about 45 Chinook, July about,18 Chinook, August about 18 Chinook, and September about 8 Chinook; totaling less than 100 Chinook for the period May-September. Page 27 of the subject report then applies genetic analysis to provide quantitative estimates of stock composition of Chinook consumed by resident killer whales by month and stock. For instance, showing in the month of May that Upper Frazer Chinook, Middle Frazer Chinook, South Puget Sound Chinook and "other" origin Chinook salmon were eaten by resident killer whales with quantitative estimates being presented. With a sample size of about five to start with, these quantitative estimates are meaningless, all that can be reliably said is that some Upper Frazer Chinook, Middle Frazer, South Puget Sound origin Chinook salmon were consumed by resident killer whales in the month of May. Sample sizes used for stock composition of fisheries when applying genetic techniques that are deemed reliable for fishery management (n=200) exceed the total number of available samples used in this study. While useful to document "presence" in the diet, none of the quantitative estimates meet minimum sample sizes useful for quantification of stock composition.

Tim Tynan, NOAA

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

Hansen hypothesizes that SRKWs are selecting for larger Chinook salmon, but shows that the whales are switching to chum salmon later in the season. His argument could be strengthened if data were shown indicating similar selection for only the largest chum salmon, which are smaller in size than Chinook (average and range), and are a much more abundant species in Puget Sound (a more available prey item, potentially allowing for *more* selectivity?). The hypothesis that availability of large Chinook is a determining factor in SRKW population viability could be called to question if the whales are not selecting for size in chum salmon but are instead feeding opportunistically on this smaller salmonid species.

Other comments / Other studies or references that would be helpful to the Science Panel

Hansen presents dive depth data showing that 90% of recorded dives by SRKWs are to depths >25 m. He hypothesized that this dive depth data indicated that the whales were seeking Chinook salmon, which he said inhabited greater depths than other species, like sockeye salmon. This may not be a valid assumption, as sockeye may also be found at depth when approaching the Fraser River. Ford should consult with the PSC and DFO biologists responsible for managing, and analyzing data from Fraser sockeye commercial and test fisheries to better understand differences in annual and intra-annual migration behavior (depth, migration routes) between Fraser sockeye run timing groups. For example, the earliest returning sockeye (Early Stuarts) migrate through marine approach areas near the surface, whereas later returning sockeye (Adams/Shuswap) are known to migrate near the sea floor. Further, information from Groot (1981) and Groot and Quinn (1987) indicate that migrating sockeye salmon do not restrict themselves to one depth but rather have a diel vertical movement pattern. Most sockeye are found at or near the surface during the night, but in the daytime they are found in substantial numbers as deep as 48 to 60 m.

Susan Bishop, NOAA

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

Would like to see age/size of Chinook taken in summer vs winter (gets at whether SRKW are obligate or preferential for prey size) since winter Chinook are younger and smaller. How compare to what northern residents eat.

Adequate consideration of uncertainties and confounding variables

Any information that shows a wider variety of prey chosen in years of lower Chinook abundance?

Any way to look at timing of Chinook stocks relative to chum stocks, and timing of switch to chum as preferred prey species, to estimate Chinook prey availability that triggers switch.

Monika Wieland, US Pacific Whale Watch Association

*Suitability of **methods** used for the problem*

The most effective method of surveying wild killer whale diet to date; the largest data set on SRKW prey samples – all the information presented by Brad here is essential to the topic at hand

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

Good coverage of summer feeding areas (San Juan Islands), reasonable coverage of fall feeding areas (Puget Sound), poor coverage of winter feeding areas (outer coast). The diet is most uncertain from January-April.

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

The genetic data on which salmon stocks are most important to SRKWs (Upper, Middle, and Lower Fraser and South Thompson Chinook stocks during the summer months) is extremely valuable and should be a crucial component of any conservation decisions regarding SRKW prey availability.

Other comments / Other studies or references that would be helpful to the Science Panel

After this presentation a question was raised by a member of the science panel: since the whales switch from Chinook to chum salmon in the fall, why can't they do the same thing at other times of year when Chinook salmon aren't abundant? Biologically, it's something they **could** do, but culturally, it doesn't seem to be something they actually do, as evidenced by the fact that they preferentially feed on Chinook during the summer even when other salmonid species are present in much greater abundances (John Ford discussed this in his first presentation at the workshop, and provided references). As a result, I hope the science panel will consider the importance of killer whale culture in any decisions made regarding this population, and I highly recommend the paper "Culture and conservation of non-humans with reference to whales and dolphins: review and new directions" by Hal Whitehead et al, published in *Biological Conservation* in 2004. I've attached the PDF of this paper with this e-mailed form.

Questions and Issues Raised at the Workshop:

- *Translating from prey frequency to diet proportion just depends on prey body size, because more biomass equals more genetic material.*
- *KW spend perhaps 50% of their day foraging, but it depends on what is defined as foraging. Our studies found both day and night foraging. Some travel activity looks similar to foraging too.*
- *Contaminant ratio can be used to determine the origin of prey.*
- *Chinook contaminant ratio changes over the coast. Other species of salmon have very low levels of contaminants. There are differences between Fraser and Skeena but low levels. Other prey like rockfish, which are more benthic, only pick up contaminants in urban bays.*
- *How many samples are there using the three methods for one individual? Unknown, but worth looking over records to compare.*
- *Chinook can be aged from their scales.*
- *When using contaminants to identify location of feeding, both the ratio and levels matter. Could have less prey of a higher contaminant burden that overwhelms more prey with a weak contaminant signal. The current method is only being used for gross comparison of differences between groups.*
- *There is sampling bias towards fecal matter that floats because there are logistical limits on ability to sample fecal matter at depth. It is known that some fecal matter floats and some sinks. However, the results still seem to agree with other methods.*

Brad Hanson, NOAA

Spatial and temporal distribution of SRKW

Tim Tynan, NOAA

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

The standing hypothesis is that large Chinook salmon are cornerstone of the SRKW's diet, supported thus far by prey remain and fecal sample collections. But it would appear that the documented occurrence timing of the whales in inside waters is much broader than the timing of migrating Fraser and Puget Sound Chinook salmon – populations that which would be the source of larger (adult) Chinook available to the whales. Species and fish sizes sustaining the whales before and after the migrating Chinook have cleared inside waters need identification. These data may indicate that the whales are less selective, and more opportunistic, than previously believed.

Questions and Issues Raised at the Workshop:

- *Because commercial whale watching is active in summer, there is more pressure to spot and identify KW in the summer, therefore sampling varies seasonally.*
- *How do you account for effort over time or within a year? There are different methods, such as selecting a subset with consistent effort.*
- *How do you differentiate the lack of whales from the failure to sight any? A masters student found that sightings give a result pretty consistent with other measures.*

Eric Ward, NOAA

Diet (size selectivity)

Northwest Indian Fisheries Commission

General comments:

The first question is why there was a decision to go to a length-based analysis rather than an age-based analysis. Since (a) FRAM actually deals in ages better than lengths, (b) the selectivity curve is actually based on age data not lengths, and (c) the KCAL of energy available from a Chinook analysis makes more sense to be age based rather than length based (see O'Neill comments) - why were the needs and availability analyses not conducted in ages and avoid all the complications that come from basing it on lengths?

FRAM deals with length distributions on a stock by stock basis and recent examinations of the growth functions used by FRAM indicate that they may not be accurate.

Recognizing the possible biases present in the scale samples, two looks at the contribution by age of Chinook to the diet are summarized in the table below:

Data for percentage distribution of Chinook ages in SRKW diet (based on scale samples).

	Source		
Age	Ford et al. 2009	Ward et al. 2010	
2	3.8%	3.6%	
3	9.4%	12.5%	
4	43.4%	48.2%	
≥5	43.4%	35.7%	
Sample Size	159	112	

The proposed length selectivity model combined with FRAMs length distribution projections seem to result in very few age 2 and 3 Chinook contributing to the diet compared to the 10 to 15% indicated above. Also, it would be interesting to compare the length distribution of the Chinook population available as prey projected by FRAM for each time period in the San Juan Islands area during the July, August, and September time periods to that actually observed from biological samples collected in those areas during corresponding time periods. A cursory analysis we have done seems to indicate that the FRAM projection underestimates the size distribution of the available prey population. As KCALs of energy are exponentially related to Chinook length, small differences in the lengths of fish available can result in a much larger estimate of KCALs available.

Secondly, the selectivity curve generated could be viewed as a snap shot in time. Yes, given a certain availability of a size range of Chinook this is what the SRKW prefer. But it implies that if there were not enough "large" Chinook available to satisfy their needs, the SRKW would not shift down and eat smaller Chinook. This does not seem to concur with commonly accepted ideas about foraging behavior and prey shifting. Nor does it comport to the data presented within Ward's presentation or the earlier presentation by John Ford. Smaller chinook, younger age classes where part of the data set presented. Ford presented in his feeding habit talk that juveniles consume a wider variety sizes and species of salmon than adults feeding in the same area. This analysis simply determines the average size of chinook consumed by the SRKWs to satisfy their appetite during the May-September timeframe for the years sampled.

Finally, utilization of size selectivity in determining the affect of fisheries on SRKWs requires further clarifications of what risk are we seeking to avoid. The risk that SRKWs do not have sufficient chinook of a selected size (determined by an average of previous years) or that they lack enough chinook of sufficient size to fulfill their dietary requirements without seek alternative prey sources? The answer directly affects the estimate of chinook biomass available to the Southern Residents during the May-September timeframe.

We request that for the second workshop additional presentations be prepared on how size selectivity for chinook changes seasonally. What is the average size of chinook taken in the fall time frame (October-November) when Southern Residents shift their focus primarily to returning chum salmon runs. In addition, what is the size selectivity preference exhibited for chinook by the Southern Residents in the winter and spring time frames?

Angelika Hagen-Breaux, WDFW

*Suitability of **methods** used for the problem*

I was unable to find a detailed description of the FRAM analysis conducted for the size selectivity evaluation, but it is my understanding that FRAM estimates of age composition for "inland waters" were used to obtain the age composition of Chinook available to killer whales. This age composition was then compared to the age composition of SRKW diet to arrive at selectivity parameters. If the analysis of age composition in inland water was conducted similar to the analysis used for the evaluation of available kilocalories, then the author needs to consider some serious data limitations, leading to the likely misrepresentation of the age composition of Chinook available to killer whales.

The starting cohort abundances in FRAM generally represents the number of Chinook that escape to FRAM accounting areas or are susceptible to FRAM fisheries before maturation, fisheries, or natural mortality. Since only a very small proportion of two year old fish mature, FRAM generally has very large abundances of 2-year olds and successively smaller abundances of 3s, 4s, and 5s. These abundances were used (presumably after natural mortality and pre-terminal fisheries) and apportioned into inside versus outside waters using base period (AEQ?) exploitation rates. These base period rates were summed over ages and time steps. Since two-year-olds experience very little fisheries mortality, especially if AEQ discounted, the allocation of inside versus outside fish is largely driven by three and four year old Chinook.

Summarizing inside/outside proportions over ages and time steps, assumes similar inside/outside distribution for all ages and time steps, which is very unlikely.

Furthermore the inside/outside allocation has very little effect on the age composition of available Chinook, which is largely driven by the age composition of the overall FRAM cohort (after natural mortality). This would result in killer whales encountering an age composition of FRAM stocks similar to that existing in all marine waters in FRAM (after natural mortality).

A better source of age composition data would be test or purse seine fisheries occurring in comparable area and time strata as the data used to analyze the age composition of SRKW diet. A certain amount of gear selectivity could be tolerated, assuming that 2 year old fish do not contribute to SRKW diet.

Alternatively, Larrie Lavoy's "bonus analysis" determining available kilocalories not by applying selectivity, but by using FRAM abundances by age and matching age contributions to those observed in SRKW diet, could be further explored.

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

Given the great preference of SRKW for 5 year old Chinook, it might be instructive to compute a killer whale natural mortality rate for 5 year old Chinook in inside waters.

Other comments / Other studies or references that would be helpful to the Science Panel

According to the selectivity analysis, the majority of age 4 Chinook and even some age 5 Chinook are rejected by killer whales. This remarkable selectivity would suggest that SRKW are not food limited, unless factors other than preference (energetic considerations, echolocation, etc…) significantly interfere with the selection of smaller Chinook.

If these whales can afford to be "picky eaters", perhaps the age composition of the Chinook diet in the May-October time frame should not be used to assess available kilocalories. Although data might be more difficult to collect, the winter time frame, when Chinook are generally less abundant in inside waters and have a different age composition, should be examined to get a better understanding of SRKW Chinook age/length selectivity.

Questions and Issues Raised at the Workshop:

- *It seems clear that KW like old Chinook. What do they eat when old Chinook are not available? Are there enough data to estimate size selectivity over summer? How does it change? That's important but we don't quite have the data.*

Discussion on Set of Presentations

- *A model could be built to determine/predict the probability of scale detection.*
- *How do you determine what is an "independent" sample? What is an event? Confident that feeding events are independent. This question is very important because data from very small areas are scaled up to large population for selectivity models.*
- *Sharing is a very important source of energy for juveniles, which was not apparent until recent studies.*
- *The age of independence and killing own prey. Examples of individual catching steelhead and sustaining at age 3. Most mammals prolong weaning, so it may depend on next calving (~5 yrs).*
- *Foraging theory states that if multi-prey foraging is dominated by the preferred species of the predator, that indicates good, favorable times. Are KW different? KW are intelligent, so why don't they switch? Are cultural/social aspects constraining? Their feeding is not as plastic as*

expected. There is little prey-switching when Chinook are abundant, but do they slave away to hunt Chinook in winter too? They could eat other things, but seem constrained.

- *FRAM is really a coast-wide, 1-box model. Extra manipulations were required to make it 2 boxes for inland and outside waters.*
- *What is the error or assumptions of error in FRAM? Age composition index is from PSC, which can be compared with sampling efforts.*
- *It could be useful to look at scale samples and age selectivity for Chum too.*
- *It seems you are really pushing FRAM to its limits. What about run-reconstructions to weekly resolution?*
- *For the winter gap, what is the ecology of blubber? What do we know about energy stored in blubber? How critical is winter ecology to summer ecology? What about information from other marine mammals? KW are not fasting-adapted, not like other mammals. Two month fasts can occur, but no indication of condition after that point. Can pack on fat, but our knowledge is limited to their ability and the consequences.*
- *Ability to map distribution of pods is pretty good in critical habitat (small areas, summer months), but limited in year-round behavior/distribution.*
- *FRAM has a mature run. Have you considered using that as a closer age/stock composition?*
- *What about ground truthing prey genetic samples in aquaria? No, but we run other types of controls. The technology is changing.*
- *Predation is not always successful. Could potentially misinterpret non-successful predation and other behaviors too.*
- *What is the importance of minor fish? It's hard to imagine KW being 'locked' on prey. Many groundfish have been suppressed in recent decades.*
- *KW have been seen sharing all salmonids (not just Chinook). Maybe not sockeye, but that's probably because there are so few events.*
- *Are there differences in age composition and diet preferences in summer and fall/winter?*

  Differences in size. We have looked at some age structure of fall/winter, but samples are so limited by few occurrences of whales coming in.

Dawn Noren, NOAA
Whale energy requirements

Northwest Indian Fisheries Commission
General comments:

We would offer two general comments: 1) That all analyses using the data prey energy requirements should always be for the range (minimum and maximum) of requirements and not just the maximum as there seems to be some debate on whether lactating females and juveniles have increased daily FMR requirements or not (see Noren paper 2011, page 64).

2) This analysis was based on captive whale's energetic and assumptions about Southern Resident killer whale body mass. This work is a key component of both agencies' estimates of overall caloric requirements of Southern Resident killer whale population. Ground truthing should occur with field observations of feeding behavior. The response by Brad Hanson (NOAA) to this question during the question and answer session was that the calculated salmon per day consumption rates were much less. Field data observations of diet and prey consumption rates conducted by NOAA and DFO scientists should be compared to these estimates. A presentation of the results should be presented at the second workshop.

Susan Bishop, NOAA

Comments on both Noren and O'Neill

See O'Neill.

Tim Tynan, NOAA

Adequate consideration of uncertainties and confounding variables

Noren indicated that in her best professional judgement, SRKWs were not physiologically capable of loading up and storing energy (fat) for extended periods and that the animals therefore required a constant source of nutrients (fish) to sustain themselves year-round. The issues of fat storage capabilities and durations for SRKWs need to be investigated and verified. One hypothesis that should be tested is that in returning to inside waters each year in areas where abundant migrating salmon become more vulnerable as prey, the whales are behaving much like another large carnivore, brown bears. The bears congregate on salmon streams to consume fish in large quantities and to form stores of fat that sustain them through their winter hibernation period. The whales may be doing the same, plying Haro Strait to feed on abundant salmon to sustain them through the winter and early spring months. After leaving inside waters, the whales are, in essence, scratch fishing for widely distributed and unconfined schools of Chinook salmon off the Pacific coast, and it is doubtful that they could be as effective in securing the same fat loads during that time.

Questions and Issues Raised at the Workshop:

- *It is possible to get some ballpark estimates from captivity. But it's possible to overfeed and activity level in captivity doesn't represent natural activity. Permission to do this work has been limited.*
- *These values seem way too high. It doesn't make sense – they're efficient swimmers, not sprinting all the time. 5-6x is pretty standard throughout literature. Some species have even higher.*

Sandie O'Neill, NOAA

Food energy value of prey

Susan Bishop, NOAA

Comments on both Noren and O'Neill

Other comments / Other studies or references that would be helpful to the Science Panel

How does forage efficiency and availability fit with pattern, particularly as prey become critically limited? For example, ONeil stated that 3 sockeye = 1 Chinook in terms of kilocals but if sockeye are easier to find or more available (more of them, shallower depth), that would change the energy budget. That is, need to weigh what it takes to find them against the energy content of an individual fish. Conversely, foraging efficiency must be fairly good in order to find the relatively low numbers of Chinook among the millions of sockeye present in the same place at the same time. I'm not arguing that Chinook are not the preferred prey, but pointing out that foraging efficiency didn't seem to be explored in terms of the energy budget.

Tim Tynan, NOAA

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

USDA published data some time ago comparing nutritive values for Pacific salmon species:

Nutritional data for various sources and species of salmon.

Values grams per 100 gram portion

	Farmed	Wild	Wild	Wild	Wild	Wild	Wild
Protein	19.90	19.84	20.06	20.14	21.62	19.94	21.30
Lipid	10.85	6.34	10.44	3.77	5.93	3.45	8.56
	2.18	0.98	2.51	0.84	1.26	0.56	1.50
Total Saturated Fatty Acids	3.86	2.10	4.48	1.54	2.13	0.93	4.13
Total Monounsaturated F.A.	3.91	2.54	2.08	0.90	1.99	1.35	1.88
Total Polyunsaturated F.A.	2.00	2.10	1.68	0.74	1.50	1.14	1.30
Total Omega 3 F.A.	0.06	0.06	0.07	0.07	0.05	0.05	0.06

Figures from U.S.D.A. (2002)

Wondering how these data match up with the data used by O'Neil in her analysis and whether the comparative lipid components between species should also be considered when surmising relative salmon prey species nutritive values to SRKWs.

The chum salmon average weight assumed in the analysis (~8-9 lbs) is low. WDFW commercial landing data for the species in Puget Sound indicates that female fall chum average 9 pounds in individual weight and males average 11 pounds in weight.

Adequate consideration of uncertainties and confounding variables

Wondering if some reality checking of outcomes inferred by data presented in this talk is needed. Applying calculated salmon food energy value and SRKW needs, O'Neill reported that annual consumption of Puget Sound fall chum salmon alone by the 87 whales could be 1.4 to 1.6 million fish. This consumption would occur over a 1-2 month period (October-November) when the species is available in inside waters. Would the foraging effectiveness and capability (e.g., observed fish consumed per hour) of the 87 whales in an area as expansive as north-mid Puget Sound allow for a consumption level this high over a period of 1-2 months? If not, what else might they be eating? Also, note that the average annual total fall chum salmon run size to Puget Sound estimated using catch plus escapement data is 1,166,624 fish (1968-2004 data from WDFW run reconstruction database, 2007). Are the whales capable of consuming well over half the annual fall chum run size entering Puget Sound each year? Wouldn't fisheries biologists and fishers have noticed this reduction in abundance by now?

One means to reality check SRKW dietary needs and consumption estimates might be to examine the incursion of 19 SRKW from the L pod into Dyes Inlet in 1997, where the whales targeted the Chico Creek fall chum run in a confined area for about a month before leaving. Known were the number of whales, the number of days the whales stayed in Dyes Inlet, and some estimate of the likely Chico Creek fall chum spawning escapement – about 3,000 fish (goal was 18,000 fish). At the time, biologists estimated that if the 19 whales consumed 5 percent of their body weight each day, the whales would eat 6,300 pounds of chum salmon a day - or about 700 fish a day. An estimated 26,600 Chico Creek chum salmon may have been consumed by the 19 whales in the ~38 day residence period in Dyes Inlet. An extreme terminal run size for the Chico Creek fall chum population of 29,600 fish (1997 escapement plus estimated fish consumed by the whales) is within the bounds of what might be expected in an average odd-numbered year (WDFW 1991-2003 average escapement for Area 10E - Chico Creek is 42,218 fish). Does the estimated number of Chico Creek chum salmon consumed during the period by the 19 SRKWs comport with food energy and foraging capability estimates derived by O'Neill and others?

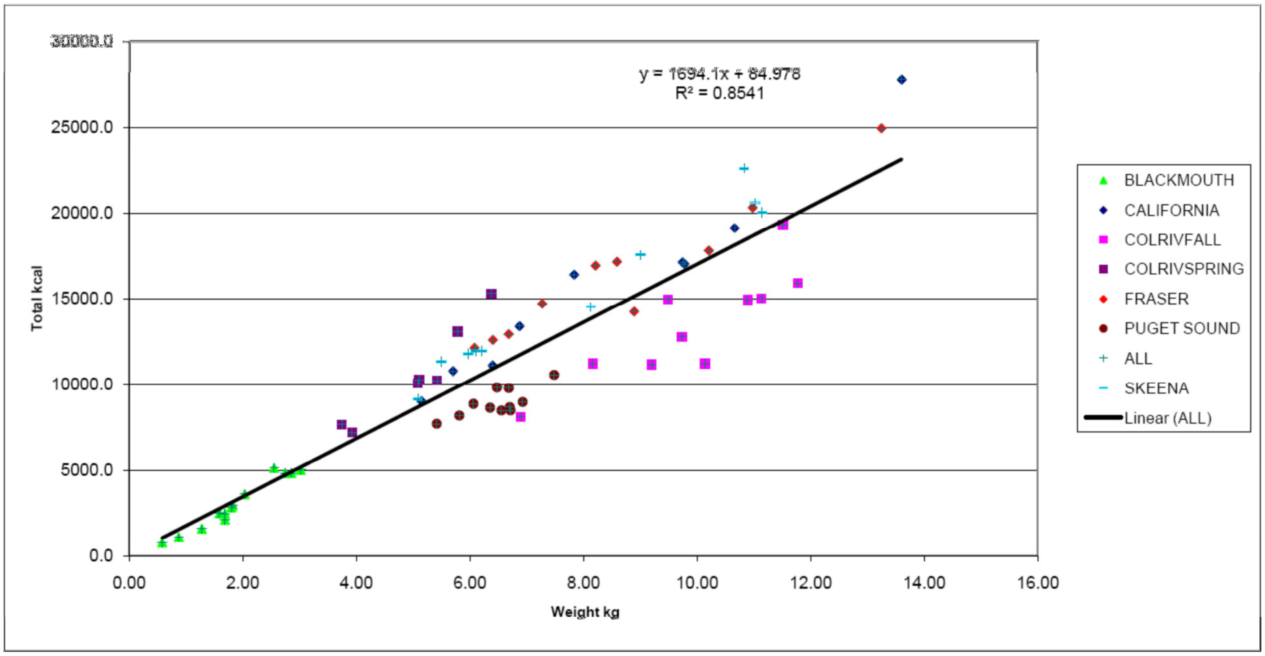
Other comments / Other studies or references that would be helpful to the Science Panel

Ewald et al., (1998) "ARCTIC VOL. 51, NO. 1 (MARCH 1998) P. 40–47 Biotransport of Organic Pollutants to an Inland Alaska Lake by Migrating Sockeye Salmon (Oncorhynchus nerka). O'Neil's presentation indicated that Puget Sound Chinook salmon may be more highly contaminated with PCBs than other populations because they originate as juveniles from a relatively industrialized area (Puget Sound) and may tend to rear for an extended period in inside (polluted) waters. Ewald et al. showed that salmon originating from pristine areas (in this case, Copper River sockeye) may also carry heavy PCB loads.

Northwest Indian Fisheries Commission

General comments:

Methodology: It was not clear how a blended sample of 2-3 fish used for KCAL analysis was assigned a length. Since energy value is an exponential function of length it does not seem that simply averaging the lengths of the combined fish is appropriate. O'Neill's original relationship was based on fish weight (We assume an average of combined samples) shown below.



It is not clear how to interpret fish size vs stock of origin differences in KCALs since all stocks were not sampled over their available size range.

The original pollution study itself is not in question. It is the application of the energy values obtained to address caloric content of the diet of Southern Resident killer whales that is in question. The length /caloric value curve was generated from a variety of life history types (spring, fall, etc.). It is not clear that these stocks are representative of the Southern Resident killer whale population's chinook diet.

O'Neill noted that the analysis was sensitivity to the removal of Puget Sound blackmouth and Puget Sound chinook. This suggests that if available KCAL estimates for the Southern Resident killer whale population is desired, then a larger sampling should be analyzed of the various chinook runs available within the population's core feeding area or range. The breadth of the sampling should be determined by whether an estimate for total KCALs available throughout the range or within the core feeding area is desired.

Questions and Issues Raised at the Workshop:

- *Chinook start to lose lipids when they start their migration. We expect lipid content to be higher off the coast, further from migration.*

- *I assume that fish have lower energy content in winter. It seems possible that fish are at their best at beginning of migration. Do KW get the same values from those winter fish? Perhaps.*

Discussion on Set of Presentations

- *Activity budgets are from summer 2006 in the San Juans. Activity is different than John Ford. Lots of travel forage? Tried to follow in winter, but not possible. Sample of 1.*
- *What is a rough estimate of total number of salmon consumed? What proportion of standing stock is this?*
- *It's important to consider both length and kCal. They are correlated but there are major differences among populations.*
- *Did you say energetic costs of growth are negligible? That should be the highest? Yes, but on context of how much they're consuming all together. Small incremental cost of growth.*
- *Might want to put some correction factor for lactating animals, as there is some emerging information available after a recent workshop. The model also assumes stepwise weaning (0 then 1), whereas it's probably gradual.*
- *Analysis presented does not account for actual window in which KW are present and overlap with prey – just an example of why differences in kcal make a difference.*
- *KW are not fasting animals – probably feeding as much as possible throughout year. Even if fasting for some period, they still need energy, whether it's eaten over time or all at once. The metabolic rate decreases somewhat during fasting but energy still required.*
- *kCals for Coho are slightly more than chum, but less than Chinook.*
- *What about foraging - kCals doesn't account for ability to find and capture. Yes, need to understand efficiency (and how it varies seasonally and with Chinook abundance), but extremely difficult. We barely know how to do this for pinnipeds, which should be easier.*

4. Status and Trends of Prey and Predator Populations

Jim Myers, NOAA

Overview of current vs. historical (1800's) abundance of major west coast Chinook salmon stocks

Tim Tynan, NOAA

Other comments / Other studies or references that would be helpful to the Science Panel

One issue that should have been described in more detail for context purposes is the high proportion of first generation hatchery-origin Chinook salmon that currently contribute to total adult return abundances of the species in SRKW feeding areas. This is important for the expert panel to understand, as in addition to current total abundances of Chinook salmon being a fraction of historical abundances, very few fish in several regions producing Chinook the whales rely on originate from natural production. In Puget Sound, a recent year average of 74% of returning adult Chinook originate from hatcheries. In the Columbia River region, about 75% of spring Chinook, 25% of summer Chinook, and 50% of fall Chinook are first generation hatchery fish. In California's Central Valley, about 90% of the Chinook returning each year are hatchery-origin fish. Significant proportions of the salmon species considered most important for the SRKW diet are produced contingent on annual funding by federal, state, and tribal fish resource agencies – a tenuous situation. The message is that in the event hatchery production is reduced or curtailed in any of these regions (e.g. state agency budget cuts are already leading to facility closures in Puget Sound; one alternative in an on-going NMFS EIS examines a 50% reduction in Chinook hatchery production in Puget Sound watersheds harboring natural populations of the species), the lost adult production will not be replaced for decades by an equivalent number of natural-origin Chinook salmon, given the degraded state of habitat and even assuming that actions to restore salmon habitat are implemented and successful. How will the dietary needs of whales be met over the short term with decreased Chinook abundance due to hatchery closures or production reductions?

Questions and Issues Raised at the Workshop:

- *How do these compare with watershed scale estimates that PSC use? We've done similar work for steelhead and they were within 20-30% - pretty close.*

Chuck Parken, John Ford and John Candy, DFO

Types of chinook salmon stocks being eaten by southern resident killer whales, and relationship of their consumption to the relative abundance of these stocks.

NO COMMENTS SUBMITTED.

Questions and Issues Raised at the Workshop:

- *NRKW and SRKW are largely found in different areas and there appears to be spatial separation in summer distributions, which implies limited opportunity for competition.*
- *The non-random selectivity is interesting. The interaction between Chinook and KW is presumably an old relationship. Stocks would presumably developed predation avoidance tactics. It seems Puget Sound Chinook can avoid but other stocks don't have the same ability? Maybe different size stocks could have evolved different tactics? Avoidance might be less important for large stocks with small predation impact. We don't have the resolution of data on migration routes to assess, but idea seems potentially valid.*
- *Might be variation in Northern diversion for Chinook.*

Robert Kope, NOAA / Chuck Parken, DFO

Recent (1970's to present) abundance trends of major Chinook salmon stocks, with special focus on Fraser River and other stocks known to be in the SRKW diet

Northwest Indian Fisheries Commission

General Comments:

The analysis was straight forward and to the point of the workshop. This was the only analysis presented on salmon abundance trends that was focused on stock groups known to comprise their diet. The results indicates that, for the key chinook stocks that comprise the majority of the diet in May- September, their abundance is stable and fishery regime changes have resulted in terminal run sizes with an increasing trend in recent years.

Later presentations which found correlations between killer whale abundance and salmon abundance were based on coast wide aggregations or some form of regional aggregations in ocean areas. These presentations warrant further examination of the strengths of their correlations of salmon abundance to SRKW population dynamics.

Questions and Issues Raised at the Workshop:

- *Any way to calculate what natural mortality has been? Can't really think of any way.*
- *There's a persistent decline among many stocks around 2004. There are other examples in other time frames. Could be poor ocean conditions, but not sure.*

Kyle Adicks, WDFW / Pieter Van Will, DFO

Trends in other known prey species, particularly chum

NO COMMENTS SUBMITTED.

Questions and Issues Raised at the Workshop:

- *The length / frequency data shown is for 2006.*
- *For Georgia Strait test fisheries, there is wide variation in run timing. This is way outside our ability to predict.*

Steve Jeffries, WDFW

Trends in other Chinook salmon predators

Northwest Indian Fisheries Commission

Comment on both S. Jeffries & Ward

General comments on these two presentations

We believe these two presentations, when considered with the presentations on current abundance trends for Chinook salmon, are intrinsically linked. Jefferies presented data indicating that:

a. harbor seal populations in BC have increased by a factor of 10 since the 1970s

b. harbor seal populations in WA have increased by a factor of 6-7 since the 1970s

c. the eastern stock of Stellar sea lions ha increased by a factor of 4-5 since the 1970s

d. the US California sea lion population has increased by a factor of 6 since the 1970s

All four of these populations inhabit the Salish Sea ecosystem for at least part of the year where they overlap with the SRKW population and all four populations are salmon predators and much of their consumption occurs before the salmon become available to SRKWs. The effect of these burgeoning populations on the abundance of Chinook salmon available to the SRKW population is likely greater, than any fishery influence. We would also note that John Ford provided data indicating the overlap of range and data by the growing Northern Resident killer whale population.

Any assessment of the status of the SRKW population and its main summertime prey base (Chinook) needs to consider the effects of these populations, as well as the Northern Resident killer whale population, on both abundance and ecosystem carrying capacity for SRKW. An ecosystem approach is critical to this kind of assessment. It seems very possible that any "savings" in Chinook due to reduced fisheries would be absorbed by these other competing marine mammal populations whose growth is already strong. I.e., there may be no benefit to SRKW. An ecosystem model might be able to address this issue. This seems especially important given indications that some of these species may be reaching a carrying capacity.

Questions and Issues Raised at the Workshop:

- *The total number of Chinook consumed is being estimated for Steller sea lions, but cannot venture a guess for other marine mammals.*
- *Scat samples are composite samples from several researchers and are just adult bones.*
- *Stellar are found at various locations – a few specific locations in WA and Long Beach rocks up to Cape Scott in BC. But they do move to inshore waters. There are some examples of concentrating at large salmon runs. But they focus on other prey species too (e.g. spawning herring in the Gulf Islands).*
- *Size calculations could be done to reconstruct size estimates of adults in scats, in order to determine if they are competing with KW for the same size Chinook.*

Eric Ward, NOAA / Jim Irvine, DFO

Preliminary thoughts on ecosystem considerations and environmental carrying capacity

Northwest Indian Fisheries Commission

General comments:

We agree with the expert panel that data exists to generate a preliminary estimate of current carrying capacity. And that the most logical place to start would be with an age structure model in this effort.

An ecosystem based approach should be considered, however, the real question is what is going on outside inland waters. The seasonal distribution and diet of SRKWs needs to be determined.

Northwest Indian Fisheries Commission

Comment on both S. Jeffries & Ward

See Jeffries.

Dave Bernard, D.R. Bernard Consulting

*Suitability of **methods** used for the problem*

Eric presented two approaches to estimating carrying capacity K for SRKW. The first is empirical using observational data, the second is reductionist modeling. Results from the first approach provided estimates of 86 to 88 whales at carrying capacity. These results were discounted because of an apparent lack of statistical significance. Perhaps they should be discounted, however, there are apparent problems in the calculations of statistical significance in the analysis judging from the presentation.

Eric presented attempts to statistically fit two simple, single-species models to count data on SKRW from 1975 thru 2010. Both attempts produced estimates of K at about 87 individuals. These results were dismissed ostensibly because once serial correlation in the fits was addressed, the parameter estimates, including the estimate for K, were apparently no longer significant (or had “nasty” posterior distributions).

My problem is that there is an apparent math error in presented equations. Perhaps I’m not getting the drift here (Eric is a fast talker), however, it’s the expressions in the slides over which I’m having difficulty. Note slide 8 with the equations:

$$w_t = zw_{t-1} + \sigma_{w^*} w_t^* \sqrt{1-z^2} \quad ; \qquad w_t^* \approx N(0,1)$$

I believe the correct equation for the residuals would be:

$$w_t = zw_{t-1} + \sigma_w w_t^* \sqrt{1-z^2}$$

Note that by definition $\sigma_{w^*} = 1$, meaning that this factor is apparently meaningless in the presented equation. The correct equation follows from the math for an autoregressive process of lag 1 year. Using Eric’s notation and a_t as white noise:

$$w_t = zw_{t-1} + a_t\,; \qquad a_t \approx N(0, \sigma_a^2)\,; \qquad \sigma_w^2 = \frac{\sigma_a^2}{1-z^2} \quad \text{or} \quad \sigma_a^2 = \sigma_w^2(1-z^2)$$

Since $w_t^* \approx N(0,1)$ is the standard normal variate, $a_t = w_t^* \sigma_w \sqrt{1-z^2}$. Perhaps this error is one of transcription only. However, the labeling of the x-axis for the posterior distribution of carrying capacity K is suspicious in slide 9. The scale is from 1 to 3, but should be centered about 80-90. Something's wrong here, and needs to be addressed.

I believe that once these errors are cleaned up, this method may prove suitable for estimating carrying capacity, at least statistically. These estimates should give NOAA pause as to the listing of this population segment. However, showing that the carrying capacity is 86-88 whales (if that is what it is) is rather unsatisfying scientifically. I would feel more confident about that or any estimate for K if some density-dependent mechanism had been identified and scientifically confirmed. That's a tough thing to do when we don't know what killed but a few whales (see Raverty's presentation).

As to Eric's second approach, multispecies modeling, I believe that the approach would only sew more confusion. Such modeling is good for answering "what if" questions, providing answers that are only as good as our understanding of processes. Such "what if" questions usually arise from impact or decisions, such as "what if" certain habitats are rebuilt or destroyed, "what if" certain fisheries are closed or open, etc. However, all these answers are conditioned what we know. In the case of SRKWs, we know very little about a very important process: death. If we don't know what kills whales, the processes in the model will be surmises that will result in radically different estimates of carrying capacity. In short, I believe that this reductionist modeling approach is an unsuitable method for estimating carrying capacity.

Tim Tynan, NOAA

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

Presentation was a very fast overview of Ward's planned work. Trusting that the variables he generally described and proposed for use in ecosystem and carrying capacity modeling are first adequately considered by the folks who derived the model input parameters/data and who best understand the input parameter/data's strengths, weaknesses, assumptions, and sources. The one proposed model input variable described that stood out immediately as questionable was based on an assumption regarding the effects of hatchery-origin Chinook on natural-origin fish fitness/productivity. This is a complex and contentious issue, and for Chinook salmon, the science is not at a state where model input data about effects on natural fish productivity and abundance can be broadly assigned and accepted as any approximation of the truth (for e.g., see Steve Schroder and Curt Knutsen's most recent Cle Elum Chinook salmon H v. W study results, which run counter to generally used fitness loss findings for steelhead from Araki et al. that are often assumed to apply for Chinook).

Other comments / Other studies or references that would be helpful to the Science Panel

There can be no doubt that first generation hatchery Chinook salmon are currently sustaining the total abundance of the species in many West Coast regions historically/currently providing SRKW prey. In Puget Sound, a recent year average of 74% of returning adult Chinook originated from hatcheries. In the Columbia River region, about 75% of spring Chinook, 25% of summer Chinook, and 50% of fall Chinook are first generation hatchery fish. In California's Central Valley, approximately 90% of the Chinook returning each year are hatchery-origin fish. Significant proportions of the salmon species considered most important for the SRKW diet are produced contingent on annual funding by federal, state, and tribal fish resource agencies – a tenuous situation. As hatchery production is reduced or curtailed in any of these regions (state agency budget cuts are already leading to facility closures in Puget Sound), the lost adult production will not be replaced for decades by an equivalent number of natural-origin Chinook salmon, given the degraded state of habitat and even assuming that actions to restore salmon habitat are implemented and successful. Will modeling take into account the standing of hatchery origin fish as a substantial proportion of total Chinook abundances, uncertainty associated with the continued availability of these fish as SRKW prey, and low likelihood for the replacement of lost adult hatchery-origin fish production by natural production over the short and perhaps long term?

Questions and Issues Raised at the Workshop:

Out of time for presentation questions. See discussion below.

Discussion on Set of Presentations

- *There is a missed opportunity to study a demographically specific dataset, which is extremely rare. Do not be too quick to dismiss age-structure models. Two important things we've learned in ecology are: 1) it is hard to study density dependence in an age-structured population without considering the actual age-structure, and 2) when density dependence does occur, it usually occurs through the young (it could be a variety of juvenile mechanisms – fecundity, etc.).*
- *There are small population issues – so few females.*
- *The wind patterns presented are just an example to show that there are spatial patterns in these oceanographic and climatic variables.*
- *It would be beneficial to know the extent to which sea lions are outcompeting KW. But sea lion predation at river mouths is on fish that already escaped KW. However, predation on juveniles could have a dynamic effect.*
- *The trends in NRKW and SRKW show impressive correlation. But is availability to Northern and Southern residents similar, or is it possible that something else is driving KW and Chinook populations?*
- *You're discounting single species models quickly and jumping into ecosystem models, which are much, much more complex and unknown. We understand single species somewhat better.*

- *We cannot make useful inferences from these models used, as they gives more than one, equally probable growth model. The results show we're using wrong models. Maybe we're better using single species models.*
- *Considering increases in pink salmon vs. chum – pink salmon increases are recent but chum declines are longer. Ruggerone has done some work on this.*
- *The benefit of using ecosystem models depends on the context. For ESA decisions, you need to look at jeopardy. Single species model might not be as useful as ecosystem models. Ecosystem models are about finding/evaluating tradeoffs in ecosystems, and exploring what happens when you perturb the system in one direction or another.*

John Long, WDFW

Catch trends, management history and stock composition of state and tribal managed salmon fisheries in north Puget Sound and adjacent ocean waters that impact Chinook impacts

John H. Clark, ADFG

Other comments / Other studies or references that would be helpful to the Science Panel

The subject presentation makes clear that the Chinook catch in Puget Sound since the early 1990s is about 10% of what the levels were prior to that time. Much of the issue at hand is whether or not fishery reductions are needed to enhance resident killer whale populations. A cursory examination of abundance trends of SRKW and NRKW as provided by Ford indicates that the upward trends observed prior to the early 1990s is similar to the upwards trends since about 2000. The dips in abundance of both populations occurred over a period of five years during the late 1990's, two years after the very severe reductions in Puget Sound fisheries.

Were reductions in Puget Sound fisheries to take place to bolster killer whale populations, one would expect a positive result. Yet, when these fisheries were actually reduced to about 10% of their prior magnitude, no such response took place. The point is, the actual experiment to test the hypotheses that reductions in Chinook fisheries would bolster killer whale abundance has already taken place with a null result. Further, any further response from fishery reductions would be but a shadow of what has already occurred.

Questions and Issues Raised at the Workshop:

- *The decline is predominantly because of management, shifting to protect weak stocks. This management shift has certainly had some successes, but the status of weak stocks is still a "mixed bag". It has been more successful than having done nothing.*
- *The most useful metric is the harvest rate of each stock, that is, how much of the stock of is being taken. We need to see total removals (abundance is important)*
- *We need to see stock by stock consumption by KW and stock by stock exploitation between Canada and the US.*

- *These percentages are available, through various sources of information – CTC, stock profiles, coast wide info. PS & Fraser. Some of the more recent composition based on DNA sampling.*
- *The pie chart is Chinook bycatch in directed SK/pink fishery.*
- *There is some fine scale information on stock composition, based on DNA sampling of fisheries, especially in the San Juan Islands. The data is very intriguing.*
- *It appears that in the past, the vast proportion of Chinook fisheries were in the winter, but those proportions only refer to the tribal troll fisheries.*
- *Over the last 4 years, some fisheries have had management mechanisms to dampen the Chinook fishery in certain areas. This has perhaps had an effect in reducing Chinook bycatch.*

5. Relationship between Chinook Abundance and Killer Whale Population Dynamics

John Ford, DFO

Overview of relationships between Chinook abundance and resident killer whale survival and fecundity

Tim Tynan, NOAA

Other comments / Other studies or references that would be helpful to the Science Panel

Ford's presentation suggests that there is a need to separately consider and manage SRKW viability requirements by life history segment, parsed by the Pacific Coastal phase (November-April); and Inside Waters phase (May-October). Which fish species and Chinook stocks are available and most important to the whales during their Pacific Coastal phase? Which Chinook and other salmon stocks are available and most important to the whales during their Inside Waters residence period? Which phase is most important for total SRKW survival and viability? If the whales are found to be like brown bears regarding importance of seasonal loading/storage of fats/nutrients to carry them through the winter, those salmon stocks available to the whales during the Inside Waters phase, and the natural habitat and hatchery programs that sustain salmon abundance there, should be the primary focus of recovery and management actions.

Dave Bernard, D.R. Bernard Consulting

Suitability of ***methods*** *used for the problem*

Method is to regress mortality indices against modeled salmon abundance over years. Method is unsuitable. Ignores serial correlation in data which will tend to make non-significant associations look significant. Should not have used running averages to calculate variables because such smoothing exacerbates the problem of "spurious regression". Did not include age or abundance of RKWs as covariates. Did not restrict RKW variable to females. Should have used increase in numbers (births – deaths) as RKW variable. Did not address measurement error in variables describing salmon abundance (panel member noted this shortcoming as well). Did not transform data to account for unequal variances for RKW mortality indices conditioned on salmon abundance index (panel member noted this shortcoming as well).

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

Abundance indices for Chinook salmon flawed because they include stocks not known to be subject to RKW predation (Oregon, Washington Coast, Columbia, NBC stocks), some stocks in the indices are doubly and triply represented, and some important stocks (some of Fraser stocks) are not represented at all. Should have used empirical information for Chinook salmon (such as CPUE statistics from the Albion Test Fishery) instead of model data. Measurement error in model inputs adds to the serial correlation in outputs beyond that naturally occurring from process error.

Adequate consideration of uncertainties and confounding variables

Obvious covariates were ignored, as well as uncertainty in variables describing salmon abundance (panel member noted this shortcoming as well). The small amount of uncertainty in variables describing abundance of RKW was noted (and appropriately so).

Validity and clarity of **conclusions** (logical path from data and analyses to conclusions)

The conclusion that "Patterns of resident mortalities and Chinook abundance are highly correlated" is suspect given the unsuitable methods used to calculate the correlations. Also, some explanation is needed on how the mortality index was calculated. A significant correlation must be put in the context of the size of the effect. That can't be done without some knowledge of how many whales one would expect to lose as salmon abundance changes (what's the slope of the regression, how many whales will be lost with say a 25% reduction in salmon abundance?).

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

Finding a defensible statistical association between salmon abundance and change rates of RKWs is a necessary condition for accepting the proposition that salmon abundance affects RKW abundance. Finding such an association means that the scientific proposition is possible; failure indicates that the proposition is impossible (at least within the confines of statistical power of the analysis). In the former outcome, science can march along to see if the proposition meets the sufficient conditions for confirmation. In the latter, science needs to look elsewhere for an explanation.

Making the results of the statistical analysis defensible will not be easy. Note that most standard statistical analyses are based on random selection of variates, no measurement error, and a process error that is normally distributed. None of these criteria are met here. Also, mortalities and births are so few as to be considered "unusual" events statistically. This statistical analysis is too important to be based on the "usual methods".

John Carlile, ADFG

*Suitability of **methods** used for the problem*

The averaging of the time series of the PSC Chinook Model abundance indices across the major ocean fisheries has problems. First, the fisheries operate under differing size limits. The proportion of the stock cohorts that are vulnerable to the fishery and therefore represented in the abundance indices vary between fisheries. Averaging across fisheries treats them as though they were equivalent. Second, the abundance indices for each fishery incorporate information from all stocks in the model. Averaging these indices will result in excess noise due to the inclusion of stocks that are not part of the Southern Resident Killer Whale's diet.

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

Any further analyses would be improved by focusing on abundance indices from individual fisheries and by the exclusion of stocks not targeted by Southern Resident Killer Whales in the calculation of the indices.

Northwest Indian Fisheries Commission

General comments:

As with all relationships of this type it is important to remember that correlation does not always mean causation. Some specific comments on the data in this presentation:

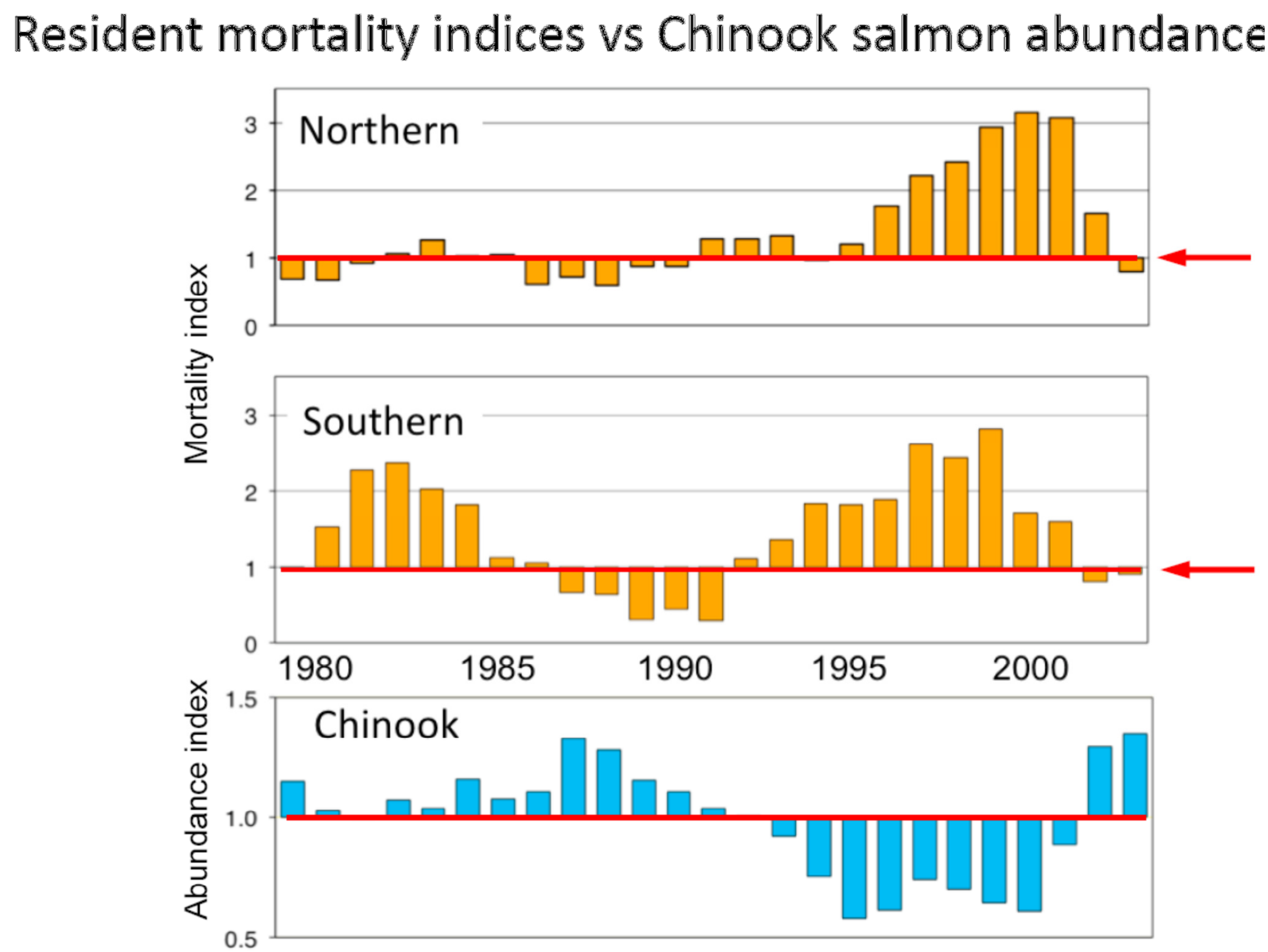
1. A large number of Chinook abundance indices were examined for correlation with the various KW population statistics - deaths and births so it is not surprising that some were significantly correlated. Rather than a broad search for correlations, a more focused approach based on some of the data presented earlier in the workshop would have been more informative. Previous workshop presentations identified the time periods, geographic areas, and specific Chinook stocks that were important contributors to the KW diet. Correlation analyses on this level would have been more informative.

2. It is important to note that the one significant relationship focused upon (between WCVI Chinook abundance index and the KW mortality index) decreased considerably when the 4 most recent years of data are included in the relationship (2005-2008); the r^2 decreased from 0.777 to 0.487 (went from explaining more than ¾ of the variation to less than ½ of the variation). Is the correlation an artifact of the series of years used?

3. It is interesting to note that the DFO analysis found a significant relationship between Chinook abundance and SRKW mortalities but no significant relationship with SRKW births while the NOAA analysis found the exact opposite (no significant relationship with SRKW mortality but a significant relationship with SRKW births).

4. Note that for the DFO mortality index | Chinook abundance index relationship (slide 16), only the most recent (1995-2000) period of increased SRKW mortality corresponds to a period of

below average Chinook abundance. For the earlier period of increased SRKW mortalities (1981-1984) Chinook abundance indices anomalies are all positive.



Laurie Peterson, WDFW

*<u>Suitability of **methods** used for the problem</u>*

The author used the PSC Chinook Technical Committee's (CTC) abundance index to assess Chinook prey availability (modified the index from the original base period of 1979-1982 to the period 1979-2003). But, I was left wondering why the FRAM Chinook abundance estimates were not used (in addition to the CTC-based estimates; i.e., compare results from the two data sources) to develop the relationship between Chinook prey abundance and mortality of resident killer whales. The author did not look at the "fisheries effect" of Puget Sound fisheries on Chinook salmon and resident killer whale survival. In this and all of the presentations, I never saw a cause-effect relationship shown that isolates the "fisheries effect" on resident killer whale survival per se; such an analysis needs to be done to really show the consequences of fishing in Puget Sound on resident killer whale survival (or lack thereof), and to better inform NOAA's present consultation regarding the Puget Sound Chinook Harvest Management Plan.

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

The author developed a cause-effect relationship using linear regression between annual indices of Chinook salmon abundance and resident killer whale mortalities for years 1979-2008 (e.g., r^2 = 0.48673, p< 0.001); but, an r^2 of 0.48673 is not necessarily a strong cause-effect relationship; there are many other sources of variation operating here, clearly; stochastic factors, many factors may be working on the mortality index for resident killer whales. It is interesting that the linear regression relationship between Chinook abundance and resident killer whale survival becomes weaker when looking at more recent years of data.

Adequate consideration of uncertainties and confounding variables

The author did not develop variances around data points presented in all graphs and tables. For the graph mentioned in #2 above, (e.g., linear regression between annual indices of Chinook salmon abundance and resident killer whale mortalities for years 1979-2008), and for a similar graph for years 1979-2004, there is higher variation when Chinook abundance is low. This result may just be error in the X values, but the author should look at the residuals to explore the implications of this pattern. Overall, it would be helpful to see variances and coefficients of variation around all estimates.

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

The author did not look at the "fisheries effect" of Puget Sound fisheries on Chinook salmon abundance and resident killer whale survival. In this and all of the presentations, I never saw a cause-effect relationship shown that isolates the "fisheries effect" on resident killer whale survival per se; such an analysis needs to be done to really show the consequences of fishing in Puget Sound on resident killer whale survival (or lack thereof), and to better inform NOAA's present consultation regarding the Puget Sound Chinook Harvest Management Plan. I would really like to see an analysis done that uses the Puget Sound fishery catch data from John Long's presentation toward looking at a cause-effect analysis on Southern Resident Killer Whale population dynamics, particularly SRKW survival over time.

Questions and Issues Raised at the Workshop:

- *For the mortality index, 1 is the expected value based on the whole period. Northern estimates are more reliable due to methodological issues, so the Northern index is used.*
- *The big difference between Northern and Southern residents doesn't seem to be in differences in mortality, so we assume the differences in populations must be from recruitment. Southern recruitment is lower than Northern (not shown)*

- *Neonatal death is death that occurs prior to 6 months. Juvenile death is death that occurs from 0.5-12 years. The birth rate only counts individuals that live past 6 months. We do not know what neonatal mortality is because of the lack of winter observations.*
- *Biologists often assume that variables are measured perfectly, which is not true and has important consequences. The effect of errors in Xs is not known but should be explored.*
- *You should compare linear and asymptotic models in the graph of Northern vs. Southern mortalities.*
- *In the graph of mortality Chinook abundance, it looks like there may be a trend in the variance. It may because of difficulty measuring, or may indicates something else going on. You should look at the residuals – might find error-in-Xs or something else going on.*

Eric Ward, NOAA / Antonio Veles-Espinso, DFO

Population Viability – Chinook Covariate Analysis

Northwest Indian Fisheries Commission

General comments:

Ward presents data showing that age of the female is the most important predictor of calving probability (as stated in his slide "Age is really important"). What we struggle with is the argument that births in the SRKW are significantly influenced by Chinook abundance.

The possible effects of the relatively large removal of individuals from the SRKW in the 1960s and 1970s for the aquarium trade have not been adequately explored in our opinion. A competing hypothesis is that the demographic impacts that these removals had on the population is the reason for their slower than expected recovery. In fact, in his opening presentation, John Ford suggested that the SRKWs had yet to recover from the influences of aquarium removals. The influence of the aquarium removals on current SRKW productivity needs further resolution.

A more thorough analysis of this competing hypothesis is needed. The removal of 35 individuals from a population of long-lived animals that only numbered in the 90 -110 range is significant.

Dave Bernard, D.R. Bernard Consulting

*Suitability of **methods** used for the problem*

In perusing the slides and my notes taken during the presentation, I had a hard time discerning what analysis has been done and what is still to come. So … please forgive me if my comments get somewhat confused.

In the cumulative covariate analysis, a statistical model was developed to estimate demographic parameters and to project population abundance of SRKWs into the future. The data upon which the model was fit were collected from 1976 – 2010 with the acknowledgment that prior to 1976, 45 individuals were removed from the population. I believe the 45 does not cover mortalities, so probably more than 45 were effectively removed. Also, most of those whales removed were probably females, given the predilection for capturing smaller whales. In 1976, only 9 females remained in the SRKW; that number has since increased to 24 by 2010.

The covariate analysis embodies the philosophy in that if you throw enough mud on the wall, something will stick. Twelve density-dependent variables out to the fifth order polynomial each with 4 density-dependent variables split into 4 subcategories each as well, 12 density-independent environmental variables, 4 anthropogenic variables, 18 stock-specific indices on salmon abundance, and 2 general indices on salmon abundance with 3 subcategories each were (will be) used to fit the model.

The result is that age drives both fecundity and survival with an abundance index for WCVI coming in a distant second. All the other covariates appeared to be inconsequential. Considering that field studies have shown a predilection of the whales to eat Fraser Chinook salmon and that the WCVI index represents only a few stocks from the Fraser River, the WCVI index probably represents the mud that stuck to the wall.

Nor did the PVA analysis provide insight into the factors that drive population dynamics of SRKWs. The PVA analysis showed that only a catastrophic event of unknown source and magnitude (a black swan?) could cause extinction of the SRKWs. While I am unaware of the supporting details for this statement, I remember Eric making it.

I believe the methods in the cumulative covariate analysis and the PVA are more a waste of time than being unsuitable. Harking back to Ecol 101, there are two basic strategies for survival of a species: r-selection and k-selection. If ever a species typifies k-selection, it's killer whales. Looking at fecundity rates and/or survival rates as functions of the environment or of abundance of some prey is what you would due with an r-selected species (herring, Atka mackerel, Pacific hake, sand lance, etc). For killer whales, such investigations would only provide ambiguous answers if any answers at all (which is what happened here). The fact that age was the most important factor in birth and death rates is what one would expect of a k-selected species that has been "pulsed fished" as has been the SRKWs.

What we should be estimating with a k-selected species is k, the carrying capacity. In killer whales that carrying capacity may be a variable, but it's probably a variable that changes slowly. Eric produced such estimates for the SRKWs in an earlier presentation (carrying capacity at an estimated 86-88 whales). Looking at the NRKWs, I think that we'll have to be patient and a few years need to pass before we can estimate carrying capacity for that population segment. Of course, the situations for both population segments are inconsistent with these segments being listed as threatened or endangered, or of being a species of concern.

Shannon Knapp, WDFW

Other comments / Other studies or references that would be helpful to the Science Panel

Errors in FRAM Chinook estimates and implications to analysis of effects of FRAM Chinook abundance on SRKW fecundity

Eric Ward presented his analysis (available previously and used in the BiOp) on the effects of Chinook abundance on SRKW fecundity, where FRAM Chinook abundance was used as the predictor variable. There was a comment from the Science Panel that pointed out that regression methods assume that the predictor variables are measured without error. In this model, FRAM Chinook was the predictor variable of interest (in addition to age and other variables tested) and that FRAM Chinook abundance had no estimate of error or precision. It is this issue that I address here.

I am not an expert on Errors in Variables (EIV) models; however, my understanding of the topic leads me to believe that, if anything, **where there are unaccounted for errors in the predictor variable (here, FRAM Chinook abundance) that the effect of that predictor on the response will likely be *underestimated*. Therefore, if a significant relationship is found between FRAM Chinook and SRKW fecundity, it would be *despite* the errors in FRAM Chinook abundance, not because of these errors.** I detail my reasoning below. Furthermore, even if error/precision estimates were available for FRAM-Chinook-abundance, I know of no way these could be appropriately incorporated into the model, as it is not a single, unified likelihood. Given this, **I feel that further exploration into the effects of errors in FRAM on the FRAM-Chinook-Abundance effect on SRKW fecundity should be given a low priority.**

Reasons to believe that errors in measurement of the predictor variable will attenuate the slope of the relationship:

(1) In the context of simple linear regression, if there are errors in the X's that are ignored,

$$\hat{\beta} \xrightarrow{p} \frac{\beta\sigma_\xi^2}{\sigma_\delta^2 + \sigma_\xi^2},$$

where $\hat{\beta}$ is the estimated slope, β is the "true" slope, σ_ξ^2 is the variance of the "true" *x*-values (not observed), in a model where the predictor values (true *x*'s) are assumed to have a normal distribution, and σ_δ^2 is the variance of the error on the observed *x*'s (also assumed to be normally distributed in this model).

That is, the estimated slope will converge in probability to the true slope (Beta) times a constant $\left(\frac{\sigma_\xi^2}{\sigma_\delta^2 + \sigma_\xi^2}\right)$ that is bounded by 0 and 1. Thus, the estimated slope converges in probability to a value that is less than the true slope (in absolute value). The estimated slope will be "less steep" than the true slope. See Casella and Berger (2002, p. 609).

While convergence in probability, does not, I believe, directly imply that $E\left(\hat{\beta}\right)=\frac{\beta\sigma_{\xi}^{2}}{\sigma_{\delta}^{2}+\sigma_{\xi}^{2}}$ (and, thus, that the steepness of the slope will be underestimated), some additional, reasonable conditions would lead to this conclusion. For example, if $\hat{\beta}_n$ are uniformly integrable (that is, $E\left(\left|\hat{\beta}_n\right|\right)<\infty$, for all *n*) then $E\left(\hat{\beta}_n\right)\rightarrow\frac{\beta\sigma_{\xi}^{2}}{\sigma_{\delta}^{2}+\sigma_{\xi}^{2}}$ (Billingsley 1995, Theorem 25.12). While I cannot provide a proof of uniform integrability, in this case it is a reasonable assumption for cases where β is estimable (has a finite estimate). Exceptions being when the response is uniformly 0 or uniformly 1 or cases of perfect discrimination (see, *e.g.*, Agresti 2002, p. 195), which was not the case with the SRKW-FRAM Chinook data.

(2) One of the approaches to dealing with EIV in simple linear regression is to use *orthogonal* least squares regression (as opposed to *ordinary* least squares regression, OLS). The regression line estimated via orthogonal regression will always lie between the ordinary regression lines of *y* on *x* and of *x* on *y* (that is the *observed* *x*'s and *y*'s, Casella and Berger, 2002, p. 583). This is generally consistent with the suggestion of Ricker (1973a) as cited in Hilborn and Walters (2003, p. 235) to take the averages of the slope of *y* on *x* and *x* on *y*.

Casella and Berger (2002, pp. 583-587) also explore a maximum likelihood solution to the EIV problem and show that (without additional model constraints) there is no unique solution for the slope (the "true" slope), but that

$$\frac{\left|S_{xy}\right|}{S_{xx}}\leq\left|\hat{\beta}\right|\leq\frac{S_{yy}}{\left|S_{xy}\right|}$$ (Casella and Berger, 2002, p. 587),

where $\hat{\beta}$ is the estimate of the slope (corrected for EIV), $\frac{S_{xy}}{S_{xx}}$ would be the slope for *y* versus *x* for ordinary least squares regression (the observed *y* on the observed *x*), and $\frac{S_{yy}}{S_{xy}}$ would be the slope for the observed *x* on the observed *y*. The key feature here is that $\frac{\left|S_{xy}\right|}{S_{xx}}\leq\left|\hat{\beta}\right|$, which implies that the slope of the observed *y* against the observed *x* will always be less in absolute value (less steep) than the "true" slope. (Note: S_{xx} and $S_{yy}\geq 0$ by definition.)

While this approach implies that the corrected solution can be approximated (*e.g.*, by averaging the slope of *x* on *y* and that of *y* on *x* or by using orthogonal regression), that would not be possible in the FRAM Chinook – SRKW fecundity analysis because (a) there is more than one predictor variable (age was another important predictor in the model) and (b) this was logistic regression, thus the response was not continuous but, instead, was 0/1.

(3) Because the theory I could find that addressed EIV models focused on ordinary regression (that is, continuous response) I wanted to reinforce that it also applied in logistic regression. To this end, I wrote an R Script that simulates data and errors applied to the *x* variable and conducts a simple logistic regression (with a single predictor variable). Initial results indicate that the addition of errors on *x* will indeed attenuate the slope – make negative slopes less negative (a positive bias) and positive slopes less positive (a negative bias), but generally the estimated slope was between 0 and the true slope (e.g., in one simulation this was true in 9,991/10,000 simulations). There is no reason to believe these general conclusions would differ for a different set of parameter values. I would be happy to share this R script if needed.

I do not think that any analysis that adds on or simulates errors on to the FRAM Chinook abundances would be of value. The effect of this should only be to further attenuate the relationship between Chinook abundance and SRKW fecundity, which would be a misleading result.

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Monika Wieland, US Pacific Whale Watch Association

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

Errors found in the "SRKWData.csv" file shared online, based on Center for Whale Research data:

J33 is listed as alive, but he died in 2010*

I'm not sure why there is an animal J99 listed – there is no whale of that designation

L7 is listed as alive, but she died in 2010

L8 died in 1977, not 1978

L11 died in 2000, not 2001

L25 has an estimated birth date of 1928, not 1925

L48 died in 1983, not 1984

L57 is listed as alive, but died in 2008

L73 is listed as alive, but died in 2010

L74 is listed as alive, but died in 2010

L117 was born in 2010, not 2011

*J1, who also died in 2010, is correctly listed as having died in 2010 in this dataset. Calves born in 2011 are also listed in this dataset, so I presume this data is supposed to be up-to-date through 2011.

While most of these mistakes are minor, I assume they could still influence the results given the relatively small sample size. Additionally, I only double-checked whale birth/death information in the dataset, but presumably there could also be errors in categories like mother's age. All of this should be double-checked and corrected.

*5. Validity and clarity of **conclusions** (logical path from data and analyses to conclusions)*

At the end of the workshop the science panel asked what SRKW decline everyone was referring to – a graph was shown indicating that adult female survivorship was relatively similar in SRKWs and NRKWs since 1980. However, a participant pointed out that Eric had removed some adult females from his analysis, as he mentioned in an earlier lecture, and he confirmed that they had not been added back in to the dataset used to make the graph discussed above. It's important to be very clear about which whales are included/excluded in any analysis like this and why. I suggest that the science panel and any researchers doing population viability analysis become intimately familiar with the population demographics of the SRKWs using a population chart produced by the Center for Whale Research. If basic information about the population is not understood, mistakes like this can happen and lead to erroneous conclusions.

6. Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

We are extremely lucky to have exact demographic data about every individual in the SRKW population, but that data is only of use to us if it is used accurately. I hope all population modeling and covariate analyses using population demographic data triple-check that their input values are correct. Any analysis based on erroneous data should be redone.

Questions and Issues Raised at the Workshop:

No time.

Brad Hanson, NOAA

Assessing the adequacy of Chinook stocks to meet the energetic needs of southern resident killer whales in their summer range

Tim Tynan, NOAA

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

Is it reasonable to accept that the 87 SRKWs are capable of consuming the number of Chinook salmon calculated as required during a month long period in inside waters – 123,000 to 148,000 fish? By Hansen's estimates, the whales would have to be effective in capturing a substantial percentage of the total adult, mainly Fraser River-origin Chinook salmon population migrating each year in the San Juan Islands/Point Roberts area – perhaps 25-30% of the migrating population. Is assumption of this foraging effectiveness ("harvest rate") realistic, considering the potential predation efficiency of 87 whales in an area that encompasses three distinct and expansive Chinook migration routes to the Fraser River (Haro Strait, San Juan Channel, and Rosario Strait)? Does the daily Chinook consumption rate required to achieve the one month prey removal estimates presented make sense when taking into account NMFS/NGO observed hourly/daily salmon capture and consumption rates per whale in the inside waters area? If not, what else could the whales by eating, or are their dietary needs being over-estimated? Are there analogous instances of other large carnivorous predators exhibiting such high fish or small animal prey capture effectiveness (e.g., sea lions and salmon)?

Questions and Issues Raised at the Workshop:

- *It is unclear how you translate prey to caloric contribution. Standardize to caloric content of species.*
- *How do you use frequency of occurrence that doesn't add to 100%?*

Session Discussion Panel

All presenters of session.

Jeff Grout, DFO

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

Ward presented a correlation between WCVI Chinook abudance index and SRKW fecundity and also indicated Fraser Late (i.e. Harrison) is best component predictor. This is an interesting finding as Parken presented data yesterday showing SRKW diet in summer months had lower Fraser Late contribution relative to available abundance in summer months. Interestingly, Harrison chinook are present on the WCVI in winter and fall months and could be a key contributor to SRKW winter feeding. However, more data is needed to determine where the SRKW reside in the winter and their diet. This speaks to need to track SRKW location in the winter months; this may strengthen the correlation analysis as salmon data is spatially and temporally rich (either with direct sampling or model based estimates of abundance).

This may have important implications for relative importance of salmon stocks in summer vs. winter periods.

Is there an opportunity to use telemetry/satellite tracking technology to determine SRKW seasonal residence patterns in winter months?

Discussion on Set of Presentations

- *What is the trend in female abundance (conflicting graphs)? Total vs. reproductive? How different is growth rate of females in Northern and Southern (doesn't appear to be mortality or fecundity)? It is a biased underestimate of the difference because Northern KW are estimated but Southern KW are censused. There haven't been temporal changes in fecundity but the difference has maintained.*
- *There is lots of serial correlation in data, which needs to be addressed. If serial correlation is present, it will affect the analyses significantly.*
- *Need to match up KW winter estimates with spatially-explicit knowledge of salmon. This is data gap, where lots of energy has been spent but is logistically difficult.*
- *We can calculate prey requirements by age. We can go further and not focus on snapshots. Could use these data to develop prey requirement time series.*
- *We would expect an age (and possibly sex) specific response to contaminant/nutritional interactions but this doesn't occur. Not sure why not.*
- *If nutritional aspects are so important, wouldn't you see it in birth rates first - save yourself first? We don't have a good answer. Could be differences in energetic requirement (and therefore constraints) between carrying fetus and calving?*
- *If there were changes during the calving season, the change could be completely missed because we can only detect calving success once it's summer.*
- *Monte Carlo runs of stochastic processes can be used to establish some form of confidence intervals around probabilities of extinction.*
- *Abundances of Chinook is the thing that can realistically be changed in world. Fisheries managers can increase future abundance (hatchery, habitat, harvest actions).*
- *Analyses looked at quasi-extinction, based on required number of mature F/M in each pod. We didn't look at extinction of age-classes. Have done 25 year projections for achieving recovery goals.*
- *KW energetics must be about supply and demand. Analyses are always looking at instantaneous demand/availability. But energy is stored in fat. When is fat accumulated and when is it used? Is instantaneous demand/availability appropriate? KW not fast-adapted, so we must assume that the kcal/day required on average are true.*

- *Vessel disturbance may be additional stress on top of nutritional stress. Poorer condition makes KW more sensitive to dying from other stressors (contaminants, disease, vessels). Good condition means KW are harder to kill and less is left to chance. Intensity is the important factor. You should take a moving average of fleet size..*
- *What is the maximum growth rate that could be expected? Which pod is highest? Caswell did work on this. 3.5%/year for Northern residents (but all together). Don't know pod specific rates.*
- *SEAK/NBC are too highly correlated to separate as drivers. Some of those stocks are being consumed. Some overlap of stocks with WCVI too. KW not foraging up there as much. But if not caught/foraged there, will they be available elsewhere later?*
- *A different interpretation of Albion fishery run timing: The change in timing is associated with changes in terminal run abundance and escapement. Genetic work doesn't imply shift in timing. 2011 will likely be anomalous due to climatic conditions, which affects catchability of test fishery.*
- *CTC vs. FRAM – subtleties. Fraser early stock – only 2 CWT stocks to represent all Fraser. Other stocks not represented but very important to KW at different times. Upper Fraser not represented.*
- *There are limitations on which stocks are represented and not represented in the CTC and FRAM models, and a desire to include better stock-specific measures in analyses.*
- *Aggregate data are problematic – combining different cohorts and abundance measures is like combining apples and oranges.*
- *Are the declines highlighted in SRKW really significant? It seems like it could just be part of longer oscillations – we wouldn't expect a monotonic increase. Those declines were highlighted due to higher mortality than expected during that time.*
- *It seems June is when availability and needs are most close and fisheries might have impact then. Have run timings changed? There has been an aggregate shift – the data are based on the historic average and current data could actually be worse.*
- *There aren't good data for growth of Northern juveniles so they cannot be compared to Southern juveniles for potential indications of nutritional stress.*
- *PVA is purely simulations, whereas analyses yesterday were about producing estimates about estimates. This is why the confidence in PVA models using single-species models that were rejected yesterday is different.*
- *We don't know what carrying capacity is so we don't know if we are near it.*
- *We haven't considered the same extent of impacts in analyses for Northern residents.*

6. Indicators of Nutritional Status and Stress

John Durban, NOAA

Body condition and growth rates of individual SRKWs

Northwest Indian Fisheries Commission

General Comments:

We feel direct observations of body condition should be considered for periodic review to establish a long-term measure of health.

The growth curve and individual growth data presented provides another perspective of whether the SRKW population is suffering from nutritional stress. This data along with that presented by Ford (DFO) would seems to indicate that current juvenile growth rates fit with the growth curve derived from the live capture data obtained in the 1960's. This may warrant closer analysis, but there does not appear to be any sign of stunted juvenile grown. This would agree with the earlier presentation by Ford (DFO) that there is no indication of a higher death rate of juveniles or decline in birth rate in the population. Taken together, the SRKW population doesn't appear to be exhibiting signs of chronic nutritional stress.

Questions and Issues Raised at the Workshop:

- *Have not been able to detect pregnancy from air so far, but would be very useful.*
- *This would be good for detecting healthy newborns, which are expected to be fat. Then we would expect changes in mother and calf in the next year.*
- *This has not yet been applied to Northern residents, though there has been lots of discussion. Lots of data from Alaska, but haven't examined those yet. Southern residents more amenable to low field costs.*
- *This could be a much more subtle/sensitive measure of condition.*

Sam Wasser, UW

Evaluation of nutritional stress using fecal hormone analysis

Patrick Pattillo, WDFW

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

Data quality was difficult to ascertain. Synchrony of hormone sample results with timing of SRKW inside feeding events appeared to be contrived to produce relevant results. Both accuracy and precision of results was questionable and no estimates of uncertainty were shown to provide perspective on significance of monthly changes in hormone levels. Data presented do not demonstrate a clear connection between hormone level and SRKW population condition.

*Validity and clarity of **conclusions** (logical path from data and analyses to conclusions)*

Speculation about the winter-spring period hormone levels or SRKW condition was without a scientific basis - no data. For example, Wasser suggested that Columbia River spring Chinook were an important diet element for SRKW, with the apparent logic that spring Chinook must be available in the spring period. This speculation had no place within this presentation and is illogical, given that all extensive tagging of CR spring Chinook show these fish are not available in the ocean off the coast of Washington or off Vancouver Island, in the spring or at any time of the year. Mature Columbia River spring Chinook enter the Columbia in January and February, and are above Bonneville Dam or in the Willamette River by March –April, so likely are not available to SRKW prior to their inside feeding period.

Northwest Indian Fisheries Commission

General comments:

The temporal data presented for the T3 hormone (which reportedly is at higher levels when body conditions are good and there is no nutritional stress) do not seem to support conventional thoughts about SRKW feeding and food availability. T3 levels are highest when whales are first observed in late April and early May after winter feeding (and when salmon are least abundant in coastal areas). The T3 level decreases throughout the early summer into August where it again increases but not to the levels seen in April|May. It then begins to decline again and is at its lowest levels in late fall (November and December). It is difficult to conclude whether this pattern is due to food abundance|availability or if it reflects a baseline cycling throughout the year in response to a combination of factors such as length of day, water temperatures, etc.

The study conclusions presented by Wasser asserts that the SRKW population return to Puget Sound "fat and happy" based on the hormone levels (T3 and GC). He contributes this to their feeding on Columbia River spring chinook returns. The observational evidence for this is sparse and the general consensus is that the winter is hard for killer whales. This presentation would lead to the conclusion that the spring time frame is the most critical for overall health. It makes up for the winter and produces the best conditions for the population based on hormone levels. The T3 levels never rebounded as high in the summer than were observed upon arrival to the core feeding area. This directly conflicts, however, to the earlier presentation by Ward that inland chinook stocks were most important to SRKWs than other groupings, such as the Columbia River stocks.

These study results only underscore the need to increase our knowledge of where the SRKWs spend their time and what they feed upon when not within Puget Sound. In addition, these conflicting conclusions underscore the need to determine how strong of a relationship these correlations with certain regional chinook stock groups are and if T3 levels in killer whales are not influenced by other sources of stress than just nutrition. It was unclear if Wasser attempted to rule out the influence of other stressors such as physical and acoustical disturbance. While the study did not try to account for the possible effect of the different pods leaving the core feeding area (San Juan Islands), Wasser did note that there was a difference in stress levels between weekday and weekend. The effect of physical and acoustical disturbance should be further assessed relative to changes in hormonal levels and spatial/temporal distribution.

Susan Bishop, NOAA

Comments on both Wasser and Ross [repeated under each]

Adequate consideration of uncertainties and confounding variables

Peter indicated that PCBE metabolites could mimic thyroid hormones. Sam's presentation with high thyroid levels at the beginning of the summer period didn't make sense given environment, more dispersed prey and migration during that time of year. Could it be that what Sam was measuring were actually PCBE metabolites rather than thyroid hormone?

John Carlile, ADFG

Adequate consideration of uncertainties and confounding variables

The nutritional stress hormone T3 shows the same general pattern each summer across years. This pattern appears to be more of a function of the yearly run timing of Chinook and Chum than it does the abundance of these species. In addition, no actual link was made between nutritional stress in the whales and actual mortalities. It appears that this stress is part of a normal yearly cycle. When does the stress cease to be simply unpleasant for the whales and become fatal? Also, the effect of vessel traffic, pollutants etc. in Puget Sound during the summer months and its effect on stress hormones in the whales was not adequately investigated.

Eric Ward, NOAA

*Suitability of **methods** used for the problem*

Methods and samples seem appropriate. I'm familiar with the work in detail, because I was recently asked to do a friendly review of the manuscript that all of this material is in (currently pre-submission stage)

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

The data are mostly from summer months. The polynomial curves shown have a few points from outside this window (early / late in the year) that have extremely high leverage. No sensitivity / diagnostics / predictive checks done. Excluding the analysis to [truncated in original]

*Rigor of **sensitivity analyses** performed on key assumptions and uncertainties*

See Comment 2 [previous].

*Validity and clarity of **conclusions** (logical path from data and analyses to conclusions)*

Honestly, I found this talk to be confusing / misleading. In the manuscript that discusses this work in detail, there is no model selection support for including Chinook as a predictor of T3 (which seemed to be the majority of slides discussed in the talk). Using AIC, they found support for a linear Julian predictor of T3 (but not Chinook), and no support for Julian predictors of GC. The curves presented here are an exploratory view of the data – fitting polynomials to data – but these aren't actually supported by their more detailed analysis of covariates!

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

See comment 5 [previous]. There seems to be support for annual differences in T3 and GC, but this is also somewhat confounded by not sampling the same individuals in each year (lots more samples needed to achieve this). All of the work is only focused on Fraser CPUE, and abundance of all other Chinook is ignored, so I think it's hard to infer much more from this work.

Gordy Williams, ADFG

*Suitability of **methods** used for the problem*

The presentation makes references to having analyzed the potential effects of vessels on SRKW health. However, only vessels in the immediate vicinity (whale watching, fishing) were part of the analysis. U.S. Coast Guard data from the Puget Sound Vessel Traffic Service (VTS) references the monitoring of over 230,000 vessels (over 65' in length) annually. This includes 13,700 deep draft ships; 2,300 oil tankers; 31,000 tugs and tows; and 176,000 Washington Ferry crossings.

The presentation notes that "SRKW arrive in early spring in the best condition of the year". Assuming that it is likely much more difficult to find large Chinook and other salmon in the ocean in fall and winter months than it is when they get in the more terminal areas in the spring and summer months, more analysis of what the issues are for them in feeding and maintaining health in inside waters is warranted. The physical presence of this many large vessels (on top the large numbers of unmonitored vessels) and the noise levels resulting from general and military vessel traffic (engines, electronics, sonar testing, etc) is very significant in both the Puget Sound and Georgia Strait areas.

The potential effects of these factors need to be a major component of any study that is looking at nutritional and psychological stress factors for SRKW.

Information on vessel traffic in Puget Sound:

http://www.uscg.mil/d13/psvts/docs/before_you_leave.pdf

Information on effects of vessels / noise on killer whales:

http://www.nwfsc.noaa.gov/research/divisions/cbd/marine_mammal/research.cfm

http://www.beamreach.org/wiki/images/d/d2/JAS00EL27.pdf

http://www.marinemammal.org/mmru/williams/Lusseau%20Bain%20et%20al%20ESR%20SRKW%20n006p211.pdf

*Validity and clarity of **conclusions** (logical path from data and analyses to conclusions)*

Analysis of effects of vessels / noise on SRKW needs to look at both vessels in close proximity to whales (i.e. whale watching vessels) and general vessel traffic / noise in making determinations of what may be affecting nutritional and psychological stress, feeding patterns / success, etc.

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

Studies have found relationships between vessels/noise and killer whale behavior and call for additional research.

Questions and Issues Raised at the Workshop:

- *Spring is most important, not winter.*
- *Columbia River suggested to be important but possibly not – Columbia fish are high kcal but small size, so they would not be contributing much energy. But Harrison fish are around in winter, much larger fish.*
- *Are there enough samples to get perinatal mortality? No, but getting good at identifying pregnancy.*
- *"Boat effects" include private/commercial whale watching and fishing boats. These are the boats with direct interference with KW. When partitioned, private boats seemed worse, but this problem is complex and needs more work. In Puget Sound, there is huge commercial and military vessel traffic, but those are not the vessels with direct interference and the analysis so far is not looking at noise pollution and other indirect stress. But have considered expanding data set.*

Stephen Raverty, UBC

Known/potential causes of death from stranded killer whales

NO COMMENTS SUBMITTED.

Questions and Issues Raised at the Workshop:

No time. See discussion below.

Discussion on Set of Presentations

- *The data are lagged by 10 days (based on swim speeds) to differentiate when the whales are encountering the fish from when the fish encounter the Albion fishery.*

- *Thyroid data will eventually be available by age/sex but just don't have good enough sample size yet. But will have 5 years of data after this year.*
- *The KW population moves in and out of area. Have not yet accounted for how that relates to stress – intend to but don't have the data. When they leave and come back there are less vessels. We have done weekday/weekend vessels studies.*
- *Different pods behave differently in spring. K pod is in best condition (among pods) at arrival, but J pod improves over season to best condition.*
- *In early spring, sampling is 60% J pod.*
- *Hope to compare hormone levels to other populations that are not nutritionally stressed or doing well (i.e. Northern and Alaska) but no resources to do that yet.*
- *Some collaborative possibilities exist for combining photogrammetry and hormone analyses to look at how rates of growth relate to testosterone levels.*
- *Don't currently have the resolution to determine within-season changes in condition, but it looks promising – the variation is greater than the error. But will need multiple years of aerial data to calibrate.*
- *What diseases do you expect to see in food-stressed animals? Many. Intestinal diseases from naturally occurring flora. KW may not be able to reject airborne pathogens that might otherwise not be able to establish.*

Peter Ross, IOS

The risk presented to southern resident killer whales by persistent contaminants

Susan Bishop, NOAA

Comments on both Wasser and Ross [repeated under each]

Adequate consideration of uncertainties and confounding variables

Peter indicated that PCBE metabolites could mimic thyroid hormones. Sam's presentation with high thyroid levels at the beginning of the summer period didn't make sense given environment, more dispersed prey and migration during that time of year. Could it be that what Sam was measuring were actually PCBE metabolites rather than thyroid hormone?

Questions and Issues Raised at the Workshop:

- *None.*

Dave Bernard, ADFG

Expectation of Mortality as a Function of Body Condition in SRKWs

NO COMMENTS SUBMITTED.

Questions and Issues Raised at the Workshop:

- *Those 13 whales were in extremely poor condition. We cannot detect condition obliquely until they are in very, very poor condition.*

Discussion on Set of Presentations

- *Eating some longer lived fish with higher accumulation of contaminants could make an important contribution to total contaminant loads.*
- *PCB and thyroid have an interaction. Study on harbor seals showed that up regulation of thyroid receptors and decrease in thyroid hormone occurred with increased PCB concentration. The mechanism is understood from rodent experiments. PCBs are persistent. Liver tries to metabolize slowly. Makes metabolytes that can be excreted. Look very similar to thyroxene and can outcompete thyroid hormone to binding to transport molecule.*
- *Harbor seals have similar ecosystem and exposure, so why not the same abundance issues as KW? Abundance of seals doesn't mean they're in good quality. KW toxicology has improved greatly, but we haven't looked at toxicology of seals and KW here until recently.*
- *Seals have had steady population growth over long time – isn't that a good indication of fitness? Quantity and quality not same. Seal populations is doing well but hit hard by disease a few years ago – high abundance did not mean good condition.*
- *Some of the non-peanut head KW might have died from old age.*
- *Are there any emerging contaminants in the region that might have a selective impact on old whales? Lots we don't know about. We tend to think of effects at bottom of food chain first, but we don't know about effects at top. Some new ones identified. It takes a long time for contaminants to decrease in population.*
- *Could increasing forage fish be as strategy to "fatten" up Puget Sound Chinook?*

7. Agency Analyses

John Ford, DFO

Overview of DFO calculations of chinook needs of both southern and northern residents

Northwest Indian Fisheries Commission

General comments:

Any analysis that makes projections of how the SRKW population will respond to any increase in Chinook abundance must account for the rest of the salmon predators in the ecosystem. All projections made at the workshop by DFO and NOAA that predict an increase in the SRKW population in response to an increase in Chinook abundance are almost certainly wrong because they do not account for how other salmon predators in the ecosystem will respond to increased Chinook abundance. These other predator populations (which are currently much larger in numbers and spread throughout the Salish Sea ecosystem) might be better able to respond to increased Chinook abundance than the SRKW population so that the KW realize very little benefit from any increase in Chinook abundance.

Questions and Issues Raised at the Workshop:

- *These numbers assume metabolic equilibrium – not gaining or losing weight. These might change with in-season growth estimates from photogrammetry once available.*
- *It might not be possible to reconcile these calculations with Peter Ross' "eating by lipid" results.*
- *Lipids are the most important kCal. Work is being done to try to refine estimates for specific stocks.*
- *When trying to groundtruth this, not as much predation is observed as predicted. But this might be because the KW are eating at night or other times.*
- *The age distribution of Chinook eaten is determined from scale samples. Not yet able to assign Chinook eaten to specific stock, but that is the next step.*
- *Some comparison to captive feeding has been done. The only available data were from a dissertation on Icelandic whales in captivity. Consistent with Icelandic whales from sea world as well. The comparisons are done by body mass.*
- *Why do the length-kCal relation? Why not take proportion of Fraser Chinook and use kCal for Fraser Chinook? Since they're twice the energy, it may explain why estimates are high and observations lower. Yes, could be – we're working on going that direction.*

Alison Agness, NOAA

Overview to the killer whale prey analysis- NMFS BiOp

NO COMMENTS SUBMITTED.

Questions and Issues Raised at the Workshop:

- *Both the effects of fisheries on prey abundance and the vessel effects of the fishery are considered in the BiOp, but only the first of those effects is addressed in this workshop.*
- *Some Chinook DPU are also endangered and have their own ESA processes (such as Section 7 consultations) occurring in parallel with other experts.*
- *How does the agency account for availability? Catch and escapement, but other removals too. We've been hearing apples/oranges comparisons.*

- *Why are the analyses restricted to Chinook when we've seen that Chum is also important in one part of the season. Can't include everything.*
- *KW are intelligent and likely should be adaptable to other prey, but they don't seem to be as flexible as expected.*
- *The BiOp is not bound to FRAM – we are open to better models if they exist or are being built.*

Larrie LaVoy, NOAA

Chinook Abundance and Food Energy Available to Southern Residents

Angelika Hagen-Breaux, WDFW

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

Rather than using FRAM's VonBertalanffy relationship for computing fork lengths by stocks and age, which is of uncertain origin and appears to be outdated for some stocks, use recent year CWT recoveries to update stock specific age-length parameters, being careful to exclude CWT data from size-selective fishing methods.

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

Preliminary analysis suggests that updating the age-length relationship for Fraser Lates, an abundant stock whose length appears to be underestimated in FRAM, would substantially increase food energy available to SRKWs.

Other comments / Other studies or references that would be helpful to the Science Panel

The large food energy increase (see item 6) that can be achieved by increasing the average length by age of a single stock, emphasizes the great sensitivity of the analysis to Eric Ward's size-selectivity function.

The length and size selectivity functions are just two of several major assumptions feeding into the analysis; other critical assumptions are the relationship between lengths and kilocalories and most notably FRAM's ability to produce regional abundance estimates by age and time step. The analysis culminates in the computation of the ratio of food energy available to food energy needs. Since this metric appears to be poorly understood; i.e. no one seems to know what an appropriate ration should be, it stands to reason why such a great amount of uncertainty would be tolerated to arrive at a questionable end.

Patrick Pattillo, WDFW

*Suitability of **methods** used for the problem*

The FRAM model appears to be the best available tool to evaluate stock specific changes in abundance due to alteration of fishing schedules. However, effects should be focused on relative changes rather than absolute values. The FRAM was built to examine relative changes in population parameters, such as spawning escapement, expected from a specific regulation change. Model builders have consistently cautioned that the precision of population specific abundance estimates from FRAM are not better and possibly are less precise than the precision of population estimate that are independently derived (i.e., not very precise).

So the estimates provided by LaVoy, presented in terms of percent change in the available abundance, may be the most robust estimates for use in evaluating the effects of large scale fishery adjustments.

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

Given the uncertainty in length distribution data in FRAM for accurate and precise depiction of population-specific growth, it may be more reasonable to generalize the analysis by simply ignoring the growth function and alternatively using age-specific effects. For example, SRKW preference for large Chinook could be reflected by focusing on the relative change in available Chinook of age 4 and older.

*Validity and clarity of **conclusions** (logical path from data and analyses to conclusions)*

Results of the FRAM application, in terms of stock composition of chinook available, may be inconsistent with the chinook stock composition of SRKW prey derived from DNA analysis. Given that 80% - 90% of Chinook prey from samples is of Fraser River origin, FRAM results may be illogical. An alternative analytical approach using FRAM, but focusing on Fraser stock output, would be informative. The same fishery alternative scenarios could be evaluated and compared, but with output being the relative change in available Fraser River Chinook.

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

It is important to ensure that analytical applications do not exceed system uncertainties. Simplification of analytical approaches in the early stage of the investigation will help maintain credibility of scientific basis.

Northwest Indian Fisheries Commission

General comments on FRAM model use and projections:

While the FRAM model is recognized as the best available tool for use in current fishery preseason planning and post-season evaluation of fisheries for southern US fisheries, its application and modifications for this particular problem seem to exceed its capabilities and one must question whether they are relevant at all. Specifically,

1. Methods were devised to predict inshore and offshore distributions of stocks by area and time. Time and area specific predictions of Chinook abundance have been the "holy grail" for management models for decades and hundreds of thousands of dollars have been spent to develop this type of model using CWT, GSI, and other data but to no avail. If this simplistic approach had any merit it would have been implemented long ago. Bastardizing a model judged to be the "best available science" for management purposes does not make it the "best available science" for its new implementation and use.

2. FRAM is an annual age-specific model, it was designed primarily to predict annual overall impacts of fisheries on age-specific estimates of stock abundances. While it uses stock-specific growth functions to predict how many fish of a stock may be subject to fisheries with size limits, this particular function has not been critically reviewed. Recent work using stock-specific growth estimates based on CWT recoveries to evaluate these FRAM growth functions indicates that many of them are incorrect and need to be revised. It seems a stretch to believe that FRAM can accurately predict stock specific length distributions for the populations available as prey to SRKW.

Killer whale experts should collaborate with DFO, NOAA, state, and tribal fisheries biologists to understand the problems with estimating local Chinook stock composition and abundance. It is unlikely that FRAM single pool abundance estimates can be parsed accurately to index local abundance in key SRKW feeding areas.

Questions and Issues Raised at the Workshop:

- *The sequence of FRAM is to take off natural mortality, then the fishery, then the remainder is available for KW. But KW consumption 10x natural mortality. Isn't KW predation part of natural mortality? Yes, but we may be underestimating natural mortality.*
- *Natural mortality comes off at beginning of time period but is prorated based on period length because the mortality estimate is annual, but the periods are sub-annual.*

Larrie LaVoy, NOAA

Which fisheries affect prey availability and to what extent? Reduction in Chinook Abundance and Food Energy from Fisheries

No comments specifically on this presentation – many comments above apply to both presentations.

Questions and Issues Raised at the Workshop:

- *Are the kCal available in a month the amount of kCal in the water during that time? Yes, after natural mortality and after pre-terminal fisheries. Some of the fish mature.*
- *Are the estimates of kCal available similar to Ford's estimate of need? Not sure, different scale, would have to look at it more closely.*

- *There appears to be a fundamental problem with double counting of the removal of Chinook by KW. Isn't there need for model that does simultaneous removal? Embedded in the model, mortality includes KW but the mortality parameters seem to be very low.*
- *There have been increases in other marine mammals, increasing Chinook mortality from other sources. Cohort model needs to treat KW as another fishery.*
- *Under the most aggressive management action, eliminating the fishery entirely, you could only increase availability of Chinook by up to 15%.*
- *Maybe it's more accurate to describe the kCal available as the surplus kCal for growth or for recovery. Yes, it is the kCal availability after KW eating which is just sustaining the current population.*

Discussion on Set of Presentations

- *We're seeing KW switching from Chinook to Chum at the end of the season. So selectivity is not likely to look the same in the winter as it does in the summer – KW will eat other things. But the model assumes the same selectivity in winter - this is a gap. The size selectivity might result in KW not eating anything. The size selectivity might need to be function of time period. But models show plenty of large Chinook in coastal waters in October to April.*
- *I get the sense that the whale models and fish models don't balance. How to balance them - can't keep selectivity unless it changes, or if certain % feed coastally, etc. We need to evaluate mortality. We're confident in the abundance and age of Chinook, but less confident in the division between inland and coastal waters. The fisheries information are all old – these fisheries have often not even been occurring in recent years.*
- *You didn't discuss variation in estimation of escapement of different stocks and the effect that would have. For example, we don't estimate every river, and some of them are only indices not meant for this type of analysis. But the flaws in FRAM on this issue are the same as flaws in the CTC model – the same data issues.*
- *It would be helpful to characterize scale of bias in escapement estimates. For example, the Thompson River can be out by 30% between different estimate methods.*
- *The time step of FRAM is 4 periods over 19 months.*
- *Assuming that KW consume Chinook all year, are there stocks that KW could feed on that are not included in model? Yes, for example large Columbia River Spring Chinook - but they're not included because of low ocean fishery impact. The Klamath River and stocks in southern Oregon are also not included.*
- *How would an increase in natural mortality change the percent reduction estimates? Not sure.*
- *Are we talking about average needs, because endangered species should be concerned with what happens in bad years and the frequency of difficult years may increase? The primary intent of this analysis is the effect of fisheries under the PST / PS RMP plans – it is not intended for looking at difficult conditions. But the BiOp looked at ranges of years.*

- *The analyses all look at the present sense, but fisheries look at the future too. Is there any place in analyses to look at effects of over/under escapement on rebuilding and future KW needs? FRAM doesn't have rebuilding ability – it is only a single year model. The Chinook BiOp does look at longer term, but not in terms of KW needs.*
- *Escapement monitoring changes over time, so are escapement estimate biases changing too? Are fisheries selectivity changing over time? Yes and no – it depends where. Fisheries have changed, now with more emphasis on mark-selective fisheries. Also, changes in gear and more river type issues. Fraser indices have been standardized over a long period, but there have been changes in methodologies in other locations. Even with standardized methods, there is still inter-annual variability in indices.*
- *Does FRAM use year-specific gear? FRAM uses actual catch levels. Then modify what was actually caught to match regulation.*
- *Are there other fisheries plans up for review where KW will be on table? There are longer term consultations for the PST (10 years). Most are in place but there are triggers for reassessment if new information becomes available.*
- *Are we trying to overthink this? If SRKW are in equilibrium with current Chinook availability, then if fishery goes up, KW goes down. But can we do big picture – reduce fishing pressure? We continue to do modeling/analysis, which currently shows that in order to have major effect, we would need major restrictions.*
- *Given the relevance of fisheries to KW recovery planning, why isn't KW recovery in model? We have not established that fisheries are actually an adjustment knob – there are lots of confounding factors. There are decisions to be made and we need to have confidence that the decisions are based on good knowledge of the connections. Reduced fishing pressure is not part of the recovery strategy. Fishing has only been identified as a potential pressure.*
- *What is the reason behind the shorter particular time frames used in the FRAM analyses? Need to have a consistent time period, and fisheries levels were so much higher before 1994 that it would take massive manipulation to get them to line up with current practices – fisheries were so vastly different in the past.*
- *There will be no extension of scope in future workshops (expanding to habitat, etc.), but there will be expanded participation, responding to the first workshop.*

Alison Agness, NOAA

Chinook Needs of Southern Residents and Ratios of Chinook Available : Whale Needs

John Carlile, ADFG

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

There was scant data on the percentage of Chinook in the Southern Resident Killer Whales diet during the winter months and the averaging assumption used to derive the percentage of Chinook in the whales' diet during the spring months seemed suspect. Prior to the arrival of maturing

Chinook in the summer months one would expect that the percentage of Chinook in the spring period would more similar to the winter period than an average of the winter and summer periods. Overall, my impression was that the uncertainty in the data regarding the Kcals from available Chinook and on the number of assumptions about the Kcal needs of the whales swamped whatever precision they were hoping to obtain in quantifying the ratios or interpreting them.

Adequate consideration of uncertainties and confounding variables

The most troubling aspect of this analysis was the blurring of line between Chinook as preferred prey and "needed" prey. The assumption being posited is that if resident killer whales can't access their preferred prey species in adequate numbers then they will starve to death. This assumption seems highly suspect given the fact that these animals are highly intelligent apex predators and that the species occurs around the globe including places where there are no Chinook salmon. It is readily apparent that the Southern and Northern Residents prefer Chinook salmon. It makes logical sense as well. Chinook grow very large and have high lipid content. Chinook give them the most bang for their buck. However, that does not mean that the absence of Chinook salmon spells doom for the killer whales. I prefer steak but if it's not available I'll eat hot dogs. I'm smart enough to know that if I can't eat my preferred food then I need to eat something else. The whales are smart to enough to know this as well.

John H. Clark, ADFG

*Suitability of **methods** used for the problem*

FRAM results are misinterpreted.

*Quality of **data** used in these methods (adequate coverage in space and time?, 'reasonable' accuracy and precision given the intended uses?)*

On page 10 of the presentation, the estimate used for % Chinook in the diet of killer whales during October-April is unreasonable. Sampling data available for this time period is for the period October-January and the proportion of Chinook in the diet averages only 24%. The authors' assumption that Chinook represent 85% of the diet of SRKW in the un-sampled months of February, March and April is a completely unreasonable assumption. Yet, this value was used in combination with sampling data during the first 4 months of the October-April period to fudge an estimate for the Chinook portion in the diet over the entire 7 month period of 58%, a weighted mean between data available for the period in question and the period after the period in question. A rational and supportable proportion should be used instead.

On page 13 of the presentation, statistics are provided which are intended to be ratios of Chinook available over dietary needs of killer whales. All ratios provided are biased low due to a lack of understanding of FRAM data concerning Chinook abundance. The FRAM model incorporates natural mortality prior to estimating Chinook available for harvest or catch. Thus Chinook consumed is already accounted for making all of the ratios shown biased low. The numbers of

Chinook calculated are not the number available for killer whale consumption but instead are the numbers remaining after predation and consumption by killer whales.

FRAM estimates are based on commonly used estimates of escapement which for many of the stocks are biased low. For instance, work in Puget Sound through the LOA has demonstrated that accepted agency produced estimates of natural escapement in Puget Sound are significantly biased low. Other work has shown that due to straying of hatchery fish, exploitation rates assumed for natural stocks is too high. Both of these kinds of problems result in FRAM estimates being underestimates of the total numbers of Chinook available for catch and escapement after natural mortality.

Lots of other problems with the analysis exist as well.

*Validity and clarity of **conclusions** (logical path from data and analyses to conclusions)*

The effectiveness of killer whale predation is an unknown. In other words, how many fish need to be in the environment for effective predation is a complete unknown. Thus the ratios provide meaningless information even if they were calculated in an unbiased manner which they were not.

Implications of above comments/concerns for NOAA and/or DFO analyses, including recommendations for further analyses

Given data deficiencies and lack of understanding of the effectiveness of SRKW feeding behavior, it is difficult to find value in this approach.

Other comments / Other studies or references that would be helpful to the Science Panel

The extensive analysis NMFS has conducted including kcals of Chinook from different localities, efforts to estimate prey/predator kcals available, etc, will not provide meaningful information. There are numerous data gaps making such calculations difficult, but more importantly, there is no basis to decide if a ratio calculated correctly is adequate or inadequate because there is not a reasoned method by which to estimate predation effectiveness. Nor is effectiveness likely to be knife edged.

Questions and Issues Raised at the Workshop:

- *Does the proportion of Chinook in diet (58%) account for differences in size and calories? The figures are just straight percentages based on the proportion of prey in KW diet based on scales samples.*
- *A comparison to other ratios might be useful. These analyses are just focused on the one predator. But the ratio will depend on the number of apex predators. If there is one predator only, this should mean lower ratios.*
- *When other ratios are calculated there should also be a selectivity function – need to make sure that any comparisons are actually comparing the same thing*

- *This is confusing, since yesterday's presentations seemed to say there are not enough fish, but from today's presentations there appears to be a great surplus of fish? It's hard to interpret – we cannot assume KW can access every Chinook.*
- *But it seemed that there were not enough available kCal and now there is a surplus? This analysis is coarser resolution and other studies are on particular stocks.*
- *Why would KW come inland to a smaller ratio – not sure that these ratios are valuable? Not sure either.*
- *It just seems that previous analyses started to approach Northern and Southern populations consuming all Chinook available, but now it shows excess availability?*
- *Maybe these ratios would be useful if combined with a fine scale morphologic study – the question of "is X Chinook enough" is impossible to determine except by looking at the health/status of whales.*

Alison Agness, NOAA

Change in Population Growth Rates Annually, Abundance Over Time and Population Viability

Northwest Indian Fisheries Commission

Comments on both Agness presentations

General comments:

We find the ratio of Chinook KCAL of energy available to SRKW KCAL needs from Chinook analyses to be uninformative at best:

1. While we think the range of KCAL needs by the SRKW population from Chinook can be fairly well defined. We believe that those ranges must be defined using both the Min and Max DPER requirements for each killer whale and the range of possible percentages that Chinook may contribute to the SRKW diet during the months in question (July, August, September).

2. We have previously described our reservations (in our comments on the L. LaVoy presentations) about the FRAM model's ability to accurately predict Chinook abundance by stock, size, time period, and geographic area. Because FRAM is a deterministic model, we have no sense of the possible variability of these projections of KCALs available.

3. The presentation provides no basis for interpreting these ratios (is 4.0 adequate, 10.0, 20.0?).

4. Based on the analyses presented, Coastal ratios during the July-Aug-Sept time period are about twice as high as for the inland area. This leads to the questions why the SRKW population spends the majority of its time in the inland area during this time period if food abundance is so much greater in the coastal area. It there was insufficient food available inside, based on what the ratios indicate, wouldn't they just spend more time on the coast?

5. It is unclear how the various calculations of these ratios between areas and species account for possible differences in prey density or foraging efficiency?

Finally, the ratios as presented have no measure of precision (i.e., variance) associated with them. Therefore, we cannot evaluate how well these ratios are being estimated and determine whether a ratio estimated to be 4 is actually statistically different from a ratio that is estimated to be 12. More importantly we cannot determine if the reduction in a ratio, for example from 5.0 to 4.5 due to projected fishery effects, is a reduction that is meaningful given our ability to estimate the ratio. Each of the many components that are part of the calculations of the ratio is subject to error (e.g., sample error, measurement error, and model estimation error) or based on assumption. The only analysis reporting confidence intervals is for the SRKW population growth as a function of FRAM Chinook abundance relationship. And even for this analysis, it is not clear what sources of error were incorporated into the estimation framework. For example, were FRAM abundance projections treated deterministically (without error) or as a stochastic process (with variation)? Without a measure of reliability for the ratio, which is the basis for the main conclusion drawn by the analyst, we cannot properly evaluate their conclusion.

Questions and Issues Raised at the Workshop:

- *Why are these analyses restricted to looking at results over 3 years, when usually the focus time frame should at least be at the scale of a generation of the animal? The BiOp is evaluating 3 year action only.*
- *Eric Ward's PVA seems the obvious tool to use for these analyses. However, it was not available at the time.*
- *These analyses look at the fishing effect on prey abundance, not the vessel impact. What was the vessel impact? We did both but only presented prey availability impact at this workshop. We don't have a comparable quantitative measure of the impact, but it doesn't appear to be large impact. There is some potential overlap and short-term behavioral change.*
- *How does conclusion of no meaningful change compare to previous judicial decision on gravel mining? Don't think that's relevant.*
- *If we look at where KW go and the migratory path of salmon, the perceived abundance of salmon will be higher because of bottleneck concentration. Catchability of Chinook will be very high and very efficient, but I don't think coastal availability can be compared due to different effective catchability. Agreed, but we just don't have the data so we can't evaluate that.*

Discussion on Set of Presentations

- *Basic ecology dictates using density on the X-axis rather than abundance, which could probably be done. Yes, but we cannot resolve availability of Chinook in space. This is another difficult metric to interpret. There is a strong desire to have small-scale Chinook abundance modeling, but we have never been successful.*
- *Ecology 101 - how do you interpret anything to do with density without addressing the basic functional response? You need functional response data and to know where you are on the curve. Agreed – this might be very easy in the San Juan Islands but difficult in the ocean.*

- *Seems like the obvious answer is to tag Chinook and track where they go. Is there any modeling of more fish in the future from habitat improvements? But we don't know how you'd quantify improvements in habitat.*
- *It shouldn't be hard to have reasonable estimates of the expected benefit from habitat actions, should it? That would be very interesting modeling, but the BiOp has to focus only on reasonably certain impacts/actions.*
- *Shouldn't there be efforts to incorporate other prey into the modeling (e.g. chum in fall/early winter)? We could, but it would be difficult – we don't have those ratios for other prey and it would still be difficult to interpret. Don't know what that'll add.*
- *What outside areas are actually used in the model? The entire range (California to Haida Gwaii), then partitioned into inside (Salish Sea) and outside.*
- *Similar analysis of Northern residents seems an obvious next step? Seems like a good idea and might be able to collaborate with DFO. However, FRAM doesn't represent northern stocks, so we'd have to make a new tool.*
- *You might not need FRAM for northern stocks, since we have lots of actual data on many of the stocks over the Alaska and northern BC range.*
- *The work presented on the first day appeared very collaborative (between agencies), but less and less as the workshop proceeded. Today, we learned that KW fecundity is related to Chinook but KW mortality is not, but yesterday we learned opposite the opposite from John Ford. Also, Chuck Parken indicated aspects of FRAM yesterday that are not incorporated into today's analysis? Yes, this is a good opportunity – many tools are not known and there are many modeling approaches but it's hard to tell what's better. All this information on KW can help refine model improvements, such as KW additions to FRAM. We need new collaboration to develop common modeling framework.*
- *Analyses should project further into the future. The obligations for evaluating actions should go beyond 3 years. There is a legal time frame, but we'll never see a large impact in a 3-year period. The 3-year plan is a jurisdictional issue. The bigger question is the KW recovery plan, which concerns a much longer time frame, and we know fishing actions will continue into the future. Couldn't this analysis could be a much larger biological exercise rather than just the legal requirement? But we need to fulfill our legal obligation. It would be very difficult to estimate fishing regimes over KW lifetimes. Larrie LaVoy showed that fisheries even 20 years ago were drastically different than today. The impacts of habitat actions are incredibly difficult to project. Fisheries are managed on weak stock basis and the future fisheries context will look very different based on whether there is recovery of all stocks or all but one.*
- *Are we going to continue to use this ratio approach? There has been some talk of expanding its use, but also significant questions about its usefulness, so where do we focus resources? What is the usefulness/intent of this type of analysis?*
- *The growth rates by pod come from the output of the stochastic individual-based model.*
- *Not able to estimate pod-specific vitality – using same age-survival relationship across all pods.*

- *The change in the ratio in inland waters comes from the change in the fishery. It is only a small change, and not being able to interpret the metric (i.e. the ratio) itself makes interpreting any change in the metric even more difficult.*
- *The recovery plan is for 28 years because the PVA indicated a 7-year oscillation, so 14-year and 28-year time frames were used to capture several cycles.*
- *We don't know the actual value of the carrying capacity for SRKW, but we looked at a range of values in Wade's analysis. The recovery criterion is a target for percent growth over time, not abundance.*
- *Is there no relation with FRAM abundance and KW survival? FRAM abundance was rejected from the model selection exercise – very poor model with positive coefficient. FRAM abundance is not going to affect survival, which makes sense from a population ecology perspective.*
- *The value of 58% Chinook in Oct-April seems like it should be closer to the 24% for Oct-Jan than the 85% for May-June. This doesn't seem to make sense – how is the average calculated? There might be an error on the slide.*
- *Spring is important due to the return of Columbia River spring*
- *Can we get more information on behavioral responses from Northern KW? I'm trying to understand the ratios, but KW share and move. Agreed, this would be good. Photogrammetry might help. Another tool to assess needs in different areas is movement and activity budget monitoring. Social patterns seem to be closely related to Chinook as well. KW may weather small times of low abundance, but periods of multi-year shortages in Chinook seem to have had cumulative impacts.*
- *Knowing the carrying capacity is fundamentally critical because without that you don't know realistic growth rates. Yes, but we don't know how to address that and have no way of assessing what carrying capacity is. There is the same problem in fisheries. Maybe you need alternate population measures for recovery goals. If you have recovery metrics based on observations, they will always change with newer observations.*
- *Need to do more forecasting of Chinook abundance based on oceanographic patterns (oscillations, etc.) – we have the information, don't we? We have done some, looking at changes in PDO.*
- *Use populations dynamics to get an idea of carrying capacity – when are they growing, when are they not, and how fast are they growing. SRKW are probably close to the carry capacity of current conditions. The question for NOAA is how you increase carrying capacity enough to achieve the target growth rates. Is the focus of this a fishing regime that will cause no net impact or a fishing regime that will contribute toward KW recovery?*

DISCUSSION AND RESPONSES FOR MULTIPLE TOPICS

Discussion of "Next Steps" from Workshop

- *Lots of ideas, short amount of working time – what are your recommendations and priorities?*
- *It seems as if the cart is running over horse. There has been lots of talk about the "decline" of SRKW, but what does that mean? You need to redefine or clarify what the problem is. It seems that most important question is how has the number of adult reproductive females changed over time.*
- *One of the slides (abundance over time) showed that SRKW reproductive females have more than doubled. NRKW have not quite doubled but are still increasing. SRKW have slowed down, but there's no decline. The more interesting question is why Northern KW continue increasing and Southern KW have been slowing down.*
- *The perceived leveling off of SRKW (abundance) is an artistic interpretation of the data - they could be increasing.*
- *The listing of KW came from a 20% population decline that occurred. Females of reproductive age are not reproducing, or not as often.*
- *Births/female doesn't seem to have a trend. However, there might be some issues with the female graph as it excludes some old females early on. The bigger issue is why are there differences in reproduction between Northern and Southern KW.*
- *Based on the Caswell paper on life-history characteristics relative to growth, the elasticity shown for KW is expected for long-lived*
- *The PVA modeling for the KW status review showed significant change in survival rates across all age-sex classes. There are correlations between survival and salmon abundance that were not used here. It is not accurate to say there is no relationship between salmon and growth. Models with salmon abundance do better.*
- *From the PVA modeling, in the absence of external catastrophes, the SRKW populations should be growing. This is consistent with other modeling. KW have a low probability of natural extinction.*
- *My recollection is that certain pods produced all males, meaning likely to be no recruitment to those pods. The abundance increases but their ability to recruit disappears. This is a good point and definitely an issue with small pods. This is accounted for in the individual-based model.*
- *The first presentation by John Ford showed that KW are found worldwide, but with a latitudinal abundance trend (more northward = more numerous). Would you actually expect the growth rate of Southern KW to be as high as the Northern KW? Historically some of the largest salmon abundances have been in the Columbia/Sacramento and they're salmon specialist.*
- *We don't expect the elasticity of population growth to salmon abundance to be incredibly high.*
- *The ratio doesn't seem fruitful until it can be connected to population parameters. It doesn't seem useful now, or soon, but may be useful in the longer term.*
- *Which of these boxes [in the logic diagram connecting topics] should we focus on? Based on the workshop and workshop materials, it seems the focus should be to better relate Chinook abundance to KW population measures (population/recovery objectives). Energetics, etc. are*

useful to explain mechanisms and show that the overall relationship between Chinook and KW is a useful thing to explore. But getting to useful action is directly associated with the relationship between Chinook abundance and KW population. Work should be done on Chinook abundance, or better indices (which might be the better approach). But might not be able to do on as fine of a scale as stocks and run timing.

- *Separating Northern and Southern KW is not necessarily useful, because there is so much ecological overlap. Approach as a whole, then partition; meet the needs of both first, then specify between populations.*
- *The talks on feeding, nutrition, etc. are extremely detailed. The outside arrow [on the logic diagram, connecting Chinook abundance and KW population] seems simpler, but it's not – errors and biases in measures and indices, small sample sizes, etc. Eric Ward's approach is good, but it is state-of-the-art modeling.*
- *Many comments about the usefulness of the ratios – before jettisoning, see how much weight NOAA gives these ratios.*
- *Lots could be learned through Northern/Southern KW comparisons. Lots of opportunity for collaboration. How much work does DFO have to do before next workshop, because they might have useful approaches too. DFO looks to engage in the best ways to address these questions, and it doesn't have to be the presenters only – we could bring other staff to modeling work. Potential exploration of Northern/Southern comparisons or other interactions with oceanographic conditions. We need to think about who/what is best, but the timelines are very tight.*
- *Key purpose of this meeting is that KW are not meeting recovery goals. We're trying to understand how to meet these goals. The habitat of KW has changed through time and its ability to support the same salmon populations as in the past is no longer the same – a return to historic abundance is not realistic. Need to make more realistic goals & expectations. Need to understand if fisheries impacts are as negative, related to current realistic expectations.*
- *Major modeling difficulties are that there is major time lag between cause and effect and the population is not observed during half of the year. Mechanisms are very important to connect demography of whales to the abundance of salmon.*
- *Dams are not permanent. Yes, there are other important impacts but they are not on this table.*
- *Want to see some ground-truthing of the kCal estimates. We need more meaningful recovery metrics. We need to look at more of an ecosystem-based approach that looks at what the role of KW is, interactions with other predators, energy dynamics, and what's realistic and what can be achieved. Also, need to explore other factors still – legacy effects of live capture and what is the actual impact of contaminants.*
- *The panel should examine KW mortality and Chinook abundance and do proper statistical analyses considering that the data have not been collected through experimental design but through observation. If a relationship found, what is the mechanism. KW share prey and females are critical, so why not share with females, then females should die less, but they still do die.*

- *Two things didn't make sense. SRKW show up in best condition and then condition decreases? We need to explore that further. From the sex ratio theory in basic biology, do you expect more males when in poor condition and responses to different conditions? Ratios – how have SRKW performed under past fishing regimes with greater intensity. Some "cannots" that probably can be done: the population effects of disturbance by vessels and a better estimate of carrying capacity. KW declines occur faster than recovery, but growth rates might increase with good abundances.*
- *The purpose of the workshop was to evaluate the fishery effect (all fisheries w impact on Chinook). We need to develop tools to evaluate confidence. WDFW is available to help the panel with understanding/evaluation of FRAM. Need to look for ways to enhance confidence in FRAM and look at stock specific validation of FRAM. Need to work on improving existing tools. It's necessary to collaborate beyond Puget Sound, as FRAM is only used for southern managers.*
- *Take the historical abundance and overlay major oceanographic variables - what is expected in future? Periods of upwelling. The extent to which winds affect northern diversion might explain Northern/Southern differences. Plot densities in inland and coastal waters. There seems to be a plausible mechanism for inbreeding (some evidence of mechanism). For the longer term – tracking Chinook with tags and collaborating with Navy monitoring.*
- *We appreciate all the information. To the panel – consider research priorities for the SW research center on river and ocean conditions for impact on KW, or the effect of California Sea Lions (caloric needs and importance of Chinook in their diet too).*
- *Would it be useful to add similar comparisons suggested for Northern residents to Alaska as well. Northern KW are also listed, but Alaska populations are large and evidently very healthy. Alaska KW cover different geographic gradients, which might add insight. I'm unsure as to whether the data exists for such work or not, but theoretically it could be quite informative.*
- *Take time to reflect, prioritize, and provide feedback. But keep suggestions pragmatic – there is always much more to do than can be done. There is great collaboration between the two countries on this issue.*

General Comments – Submitted

Susan Bishop, NOAA

I would also suggest that additional work be done to assess metabolic needs, availability and some of the other key parameters for Alaska killer whales. One of the things we struggled with at the workshop was a lack of baseline against which to determine the status of various parameters for Southern Residents. Some folks suggested the Northern Residents which would be helpful, but they are also listed under SARA so not a representative healthy population. Having similar analysis for the Alaskan and Northern Residents would provide comparison to a healthy population (AK) and one under stress but still increasing (Northern Residents).

Detailed Responses to Multiple Presentations

Robert Lessard, CRITFC

Introduction to response

My comments and notes were not structured to deal specifically with individual talks. I was jotting down notes and vital rates specific to diet and mortality and writing the equations for a full-blown multi species predator prey model. Still, I would say that my comments pertain to the Ward, Agness, Ford, LaVoy, and Noren talks.

Basically, if orca predation is very substantial portion of chinook mortality, a predator prey model of orca/chinook is the only way to understand if we are actually just cycling through some normal fluctuations or entering long term declines. Such a model should include seals and sea lions too if their portion of chinook mortality is significant. I don't say this lightly. I know it's a challenge. I spent five years of my PhD fitting muti-spp predator prey models to data with varying forest veg/fire/harvest dynamics. There are not a lot of people who can fit PP models to data. That pesky functional response makes it tough, but with all diet data, it's possible, and it's the only way to explore hypotheses about the ecological dynamics of the multi-spp system.

Review of Killer Whale workshop material and proceedings

Herein I provide general comments on the subject of population dynamics modeling, fisheries interactions and ecosystem modeling. The presentations were scientifically credible and, with the exception of the FRAM model, results were unbiased and credible to reasonable accuracy. The main biases I would point to are: 1. Diet composition and 2. FRAM outputs. Diet composition seems biased toward summer sampling. Winter Chinook consumption by orcas is likely much lower and should not be extrapolated from summer. FRAM model biased to southern Chinook stocks.

Overall, the ecosystem perspective seems lost in the BiOp. Chinook are consumed by both whales and seals, not just whales. Transient whales eat seals, seals eat Chinook and resident whales eat Chinook. Granted, transient whale consumption of seals is infrequent, but when it occurs, it's significant enough to release Chinook numbers into the food chain for resident whale consumption. The multi-trophic perspective has not been addressed.

It was unclear to me from any of the presentations how management options could be examined to mitigate the alleged decline in SRKW. It was not even evident that there was any persistent decline in SRKW. If fishing regulations were on the table, it was not evident that reduced fishing would have a significant impact on SRKW. Without an integrative model that accounts for whales, seals, Chinook and fisheries, I do not know how the trade-offs could be addressed quantitatively.

Population dynamics

A population viability analysis was performed (Ward presentation) on Southern Resident Killer Whales (SRKW) using 15 years as a reference point to model the probability of extinction of a population that lives 80-90 years. Typically, for long-lived wildlife species, PVAs are performed on a time scale analogous to the lifespan of the organism, or at least several generations. The probability is so low that a population of killer whales could go extinct in 15 years that the analysis is insensitive to almost everything. Even if every female were sterile, the probability is very remote that all whales would be dead in such a short amount of time with adult survival rates at ~98%. Data records show that 351 of 665 whales surveyed in 1973 are still alive 38 years later. Perhaps another metric of population viability could be used that provides feedback on population trends on a shorter time scale relevant to management. A probability of >10% decline in 10 years

perhaps? Covariate plots show that juvenile survival decreased with the availability of Chinook from nearly all models. For the period 1987-2000, Ward shows decrease in calf survival and an increase in total adult abundance, suggesting density dependent recruitment. Adult survival did not appear to follow the same trend. It would be helpful to see some figures of simple patterns. The population dynamics model can perhaps fit some of the time trends in abundance, but the behavior of the underlying population would be easier to interpret in the context of certain population dynamics measures. For instance, plots of the following empirical trends overlain with model predicted trends:

1. B vs time
2. M,F vs time
3. dF,dM vs time
4. b per F vs time
5. b per F vs F+M
6. dF per b vs F+M
7. dF+dM per F+M vs F+m

where

B - births
M – adult males
F – adult females
dF – adult female deaths
dM – adult male deaths

Ecosystem considerations

The functional response (the way predation rates change with prey availability) is an essential component of dynamic coupling in predator prey models. The sum of births, density dependent mortality, density independent mortality and predation mortality predict net population change. The functional response was not discussed in any of the presentations, and yet it is considered pivotal in predicting the qualitative behavior of predator prey systems. When coupled with predator growth response (the numerical response), it can determine if regular population cycles are the norm. Analyses presented only accounted for net recruitment with density dependence. None of the analyses performed accounted for saturation in the consumption rate of Chinook by SRKW, nor is there a mechanistic hypothesis for the recruitment or survival of SRKWs to be tied directly to predation of Chinook. With so much attention given to “prey sharing”, the functional response is an obvious mechanism to imbed in analyses of prey consumption.

There is a multi-species modeling approach that could be taken to examine this issue. Since the problem is centered on orcas and Chinook, why not build a predator prey model with coupled dynamics between predators and prey? This model could also include the dynamics of harbor seals (HS) and transient killer whales (TKW), and perhaps California Sea Lions (CSL) and Steller Sea Lions (SSL). The harbor seals are an obvious component of Chinook predation, and since Chinook are such an important food source for resident killer whales, a model that is sensitive to the interactions between seals, transient killer whales, resident killer whales and Chinook would be valuable. Such a model would allow for explicit incorporation of the functional responses of predators and would also allow for an examination of the potential for transient killer whales to mitigate seal predation on Chinook, thereby releasing additional Chinook abundance for consumption by resident killer whales. Such a model could easily be parameterized by fitting to time series data and per-capita consumption information documented in diet surveys. Given increases in HS, CSL and SSL populations from the 1970’s until present (roughly 5 to 10 fold increases), it is surprising not to see these predators incorporated into the analysis as they are potentially consuming Chinook at about the same rate as fisheries. With such high growth rates in seals and sea lions, fisheries reductions could be compensated for by increased predation in seals and sea lions.

General comments

It is not apparent that the SRKW population is in fact declining in any persistent fashion – not as a population aggregate in any case. If there was a decrease prior to 2008 for a few years, it is still statistically evident that the long trend is of a gradually increasing population. The average rate of increase remains positive, the population remains well above 1980’s levels, and insufficient time has elapsed to declare a shift in growth rate to negative.

Bioenergetic estimates of Chinook diet requirements by SRKW are in the range of 300K-1.2M fish per year. However, there seems to be some discrepancy in how to attribute the energy requirements to species consumed. Fall diets seems to be at least 50% Chum salmon (based on DNA fecal analysis) and as high as 80% Chum. Despite the low Chinook portion in fall diets, overall estimates of Oct-April Chinook portions are given at 58% (Agness presentation). It would seem that the unknown months Jan-April should be lower Chinook portions than April-June.

A mortality breakdown of Chinook by source (whale predation, fishing, natural mortality) was not presented. There were many presentations of the diet composition of whales, including the portion of Chinook in the diet, but never the portion of Chinook deaths attributable to whale predation, and no mention is made of the portion of mortality attributable to seals (though bioenergetics showed estimates of potential consumption).

Angelika Hagen-Breaux, WDFW

Review of the Use of FRAM to Obtain Inside/Outside Estimates of Chinook Abundance

As Presented in the May 2011 Draft Biological Opinion

Review Appended to Document

Shannon M. Knapp, WDFW

Review of the Effects of Chinook abundance on SRKW Fecundity, Survival, and Population Growth

As Presented in the May 2011 Draft Biological Opinion

Review Appended to Document

Scott Pearson, WDFW

Review of Southern Resident Killer Whale Diet Selectivity, Metabolic and Calorie Needs, and Ratio of Prey Availability to Killer Whale Needs

As Presented in the May 2011 Draft Biological Opinion

Review Appended to Document

APPENDIX 1: WORKSHOP 1 AGENDA

NOAA FISHERIES SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Fisheries and Oceans Canada | Pêches et Océans Canada

EVALUATING THE EFFECTS OF SALMON FISHERIES ON SOUTHERN RESIDENT KILLER WHALES – WORKSHOP 1

Crown Plaza Hotel
1113 Sixth Avenue, Seattle, WA
September 21 – 23, 2011

Objectives

1. Establish and discuss the factual context: what do we know about threats to Southern Resident killer whales, their feeding habits, and the relationship between salmon abundance and killer whale population dynamics?

2. Present and discuss analyses done to date, including analyses done for consultations on the 2008 PST Agreement and 2011 Puget Sound Resource Management Plan, work by DFO scientists, and work by other scientists.

3. Identify and discuss key assumptions and uncertainties. Explore the potential for reducing uncertainties with additional information and/or alternative methods in the short term (i.e., prior to Workshop 2) to improve confidence in the results and address questions. Identify any other short or long term research that may contribute to reducing uncertainties.

4. Identify and assign specific follow-up tasks for completion and presentation at Workshop 2.

Workshop Agenda

September 21st, 2011 (Day 1)

8:00 am Workshop start

INTRODUCTION AND CONTEXT

Session 1 **Welcome** [40 minutes]

8:10 am Introductions and review of workshop objectives, agenda, principles, code of conduct, roles, and task process.

Dave Marmorek, ESSA

Welcome remarks from sponsoring agencies

NOAA / DFO

Introduction of Scientific Panel

Ray Hilborn, UW

Session 2 **Setting the Context** [70 minutes]

8:50 am Current status and trends of resident killer whales (current & historical abundance, trends, differences between Northern & Southern Residents)

John Ford, DFO (20 minutes)

9:15 am NOAA and DFO Recovery Plans (threats and limiting factors, etc.) and plan implementation

Lynne Barre, NOAA / Paul Cottrell, DFO (20 minutes)

9:40 am Session Discussion [20 minutes]

10:00 am **Break** **[20 minutes]**

FACTUAL CONTEXT

Session 3 **Current State of the Science on Killer Whale Feeding Habits** [2 hrs 40 m]

10:20 am Overview of resident killer whale feeding habits

John Ford, DFO (20 minutes)

10:45 am SRKW diet from prey remains and fecal samples

Brad Hanson, NOAA (20 minutes)

11:10 am Spatial and temporal distribution of SRKW

Brad Hanson / Candi Emmons, NOAA (10 minutes)

11:25 am Diet (size selectivity)

Eric Ward, NOAA (10 minutes)

11:40 am Session Discussion [30 minutes]

12:10 pm **Lunch (on your own; be back on time!) [1 hour]**

1:10 pm Whale energy requirements

Dawn Noren, NOAA (15 minutes)

1:30 pm Food energy value of prey

Sandie O'Neill, NOAA (10 minutes)

1:45 pm Session Discussion [15 minutes]

Session 4 **Status and Trends of Prey and Predator Populations** [2 hrs 40 m today; 3 hrs total]

2:00 pm Overview of current vs. historical (1800's) abundance of major west coast Chinook salmon stocks

Jim Myers, NOAA (15 minutes)

2:20 pm Types of chinook salmon stocks being eaten by southern resident killer whales, and relationship of their consumption to the relative abundance of these stocks.

Chuck Parken, John Ford and John Candy, DFO (15 minutes)

2:40 pm Recent (1970's to present) abundance trends of major Chinook salmon stocks, with special focus on Fraser River and other stocks known to be in the SRKW diet

Robert Kope, NOAA / Chuck Parken, DFO (15 minutes)

3:00 pm **Break** **[20 minutes]**

3:20 pm Trends in other known prey species, particularly chum

Kyle Adicks, WDFW / Pieter Van Will, DFO (15 minutes)

3:40 pm Trends in other Chinook salmon predators

Steve Jeffries, WDFW (10 minutes)

3:55 pm Preliminary thoughts on ecosystem considerations and environmental carrying capacity

Eric Ward, NOAA and Jim Irvine, DFO (15 minutes)

4:15 pm Session Discussion [45 minutes]

5:00 pm Wrap-up and things to ponder over dinner [<10 minutes]

5:10 pm **End of Day 1**

September 22nd, 2011 (Day 2)

8:00 pm Workshop start

8:10 am Introductory remarks, recap of previous day's main themes, and plan for Day 2

Dave Marmorek, ESSA (10 minutes)

8:20 am Catch trends, management history and stock composition of state and tribal managed salmon fisheries in north Puget Sound and adjacent ocean waters that impact Chinook impacts

John Long, WDFW (10 minutes)

ANALYSES

Session 5 **Relationship between Chinook Abundance and Killer Whale Population Dynamics** [1 hour 55 minutes]

8:40 am Overview of relationships between Chinook abundance and resident killer whale survival and fecundity

John Ford, DFO (15 minutes)

9:00 am Population Viability – Chinook Covariate Analysis

Eric Ward, NOAA and Antonio Veles-Espinso, DFO (20 minutes)

9:25 am Assessing the adequacy of Chinook stocks to meet the energetic needs of southern resident killer whales in their summer range

Brad Hanson, NOAA (10 minutes)

9:40 am Session Discussion [35 minutes]

10:15 am **Break** **[20 minutes]**

Session 6 **Indicators of Nutritional Status and Stress** [2 hours 10 minutes]

10:35 am Body condition and growth rates of individual SRKWs

John Durban, NOAA (15 minutes)

10:55 am Evaluation of nutritional stress using fecal hormone analysis

Sam Wasser, UW (15 minutes)

11:15 am Known/potential causes of death from stranded killer whales

Stephen Raverty, UBC (10 minutes)

11:30 am Session Discussion [30 minutes]

12:00 pm **Lunch (on your own; be back on time!)** **[1 hr 10m]**

1:10 pm The risk presented to southern resident killer whales by persistent contaminants

Peter Ross. IOS (15 minutes)

1:30 pm Expectation of Mortality as a Function of Body Condition in SRKWs

Dave Bernard, ADFG (10 minutes)

1:45 pm Session Discussion [15 minutes]

Session 7 **Agency Analyses** [2 hours 40 minutes (today); 4 hours 10 minutes (total)]

2:00 pm Overview of DFO calculations of chinook needs of both southern and northern residents

John Ford, DFO (15 minutes)

2:20 pm Overview to the killer whale prey analysis- NMFS BiOp

Alison Agness, NOAA (10 minutes)

2:35 pm Chinook Abundance and Food Energy Available to Southern Residents

Larrie LaVoy, NOAA (20 minutes)

3:00 pm **Break** **[20 minutes]**

3:20 pm Which fisheries affect prey availability and to what extent? Reduction in Chinook Abundance and Food Energy from Fisheries

Larrie LaVoy, NOAA (20 minutes)

3:45 pm Session Discussion [1 hr]

4:45 pm Wrap-up and things to ponder over dinner [<15 minutes]

5:00 pm **End of Day 2**

September 23rd, 2011 (Day 3)

8:00 pm Workshop start

8:10 am Introductory remarks, recap of previous day's main themes, and plan for Day 3

Dave Marmorek, ESSA (10 minutes)

8:20 am Chinook Needs of Southern Residents and Ratios of Chinook Available : Whale Needs

Alison Agness, NOAA (20 minutes)

8:45 am Change in Population Growth Rates Annually, Abundance Over Time and Population Viability

Alison Agness, NOAA (15 minutes)

9:05 am Session Discussion [40 minutes]

9:45 pm	Wrap-up – Concluding Workshop 1, Looking toward Workshop 2 [<15 minutes]
10:00 am	**Break** **[20 minutes]**
10:20 am	Flexible Time: More discussion with participants or Science Panel time
12:00 pm	**Lunch on your own** **[1 hour]**

<u>SCIENTIFIC PANEL</u> To be attended only by the Science Panel

1:00 pm	Review of Topics by Topic Leads & Contributors; Feedback from other panel members [1 hour 50 minutes]
2:50 pm	**Break** **[20 minutes]**
3:10 pm	Writing and Further Discussion; Next Steps
5:00 pm	**End of Day 3 – Workshop finished**

PROCESS DESCRIPTION

July 28, 2011

A Bilateral Scientific Workshop Process to Evaluate Effects of Salmon Fisheries on Southern Resident Killer Whales

Background and context: Southern Resident killer whales (*Orcinus orca*) are listed as an endangered species under both the U.S. Endangered Species Act (ESA) and Canada's Species at Risk Act (SARA). The National Marine Fisheries Service (NOAA Fisheries) and Fisheries and Oceans Canada (DFO) have developed and adopted recovery plans as required by their respective statutes. These recovery plans present the biological status of the population, describe threats and factors believed to be limiting recovery, establish interim recovery objectives and identify critical uncertainties. They prescribe actions to address the threats and limiting factors and call for research to address critical uncertainties and data gaps.

Both recovery plans identify several threats to killer whale recovery – environmental contaminants, insufficient prey, physical disturbance by vessels, noise pollution, oil spills, diseases, climate change, small population size, cumulative effects – but due to insufficient information generally do not characterize the absolute or relative importance of these threats. NOAA Fisheries and DFO have undertaken research to better understand these threats. They also have initiated and/or continue to support or conduct a wide range of actions to address the identified threats. For example, the agencies support efforts to restore and protect salmon habitat to improve salmon abundance. They have promulgated regulations designed to limit physical disturbance of whales by vessels, and to limit noise pollution in areas frequented by the whales. They have reviewed proposed actions within their respective jurisdictions for potential negative effects on killer whales and have used their authorities to prescribe measures to mitigate such effects. This workshop process described herein is not intended or designed to undertake an extensive review of all of the threats or the comprehensive recovery programs.

In addition to the development of recovery plans, the listing of a species under the ESA or SARA requires the applicable U.S. or Canadian federal agency to consider the potential effects of various management actions on that listed species. In the case of the ESA, the purpose of this evaluation – set forth in a "biological opinion" – is to determine whether the implementation of the proposed action will jeopardize any listed species or result in the adverse modification or destruction of designated critical habitat. With respect to fisheries and killer whales, the evaluation focuses on the effects of fisheries by reducing the abundance of salmon prey – particularly Chinook salmon – available to the whales in relation to their metabolic requirements.

Pursuant to this ESA requirement, NOAA Fisheries in 2008 conducted an evaluation of new eight-year fishing regimes recommended by the Pacific Salmon Commission for U.S. and Canadian fisheries covered by the Pacific Salmon Treaty. This analysis focused on the estimated reduction in Chinook salmon available to the whales from the proposed fisheries in relation to the whales' estimated prey requirements. Using the best information then available, NOAA Fisheries concluded that the proposed regimes would not jeopardize the killer whales or adversely modify their critical habitat, but also noted that new scientific information would continue to emerge that would help inform future consultations.

In 2010, the Washington Department of Fish and Wildlife and the Puget Sound treaty Indian tribes submitted a proposed new fishing plan that would govern their Chinook salmon fisheries in Puget Sound for the next several years. NOAA Fisheries again evaluated the effects of fishing on the abundance of prey available to the killer whales using a similar approach to the 2008 analysis, but incorporating new scientific information available since 2008. This newer analysis suggests that the amount of Chinook available to the whales in comparison to their metabolic requirements may be less than what was estimated in 2008. This change results from several factors, including but not limited to revised estimates of the metabolic requirements of the whales, their selective preference for larger Chinook salmon and inclusion of a broader range of years to represent expected variations in the annual abundance of Chinook salmon. In addition, NOAA Fisheries developed new analyses regarding the relationship between Chinook salmon abundance and Southern Resident killer whale population growth.

NOAA Fisheries and DFO are mindful of the potential significance of this new information to fisheries and other activities that affect the abundance of Chinook salmon available to the killer whales. For this reason, NOAA Fisheries and DFO want to ensure that their scientific data and analyses are carefully reviewed in an open and scientifically rigorous process. The bilateral workshop process described herein was conceived and designed with these purposes in mind. It will provide a structured and focused scientific forum wherein NOAA and DFO scientists and other invited experts can interact with an independent Science Panel to review the best available scientific information on the effects that salmon fisheries may have on Southern Resident Killer Whales by reducing their prey. The panel and workshop participants will review the ecology of the whales and their feeding preferences and energy requirements. They will examine the extent to which various salmon fisheries may reduce prey available to the whales, and the potential consequences to their survival and recovery. This focus on the effect of fisheries does not suggest that fisheries are believed to be the primary cause of the whale population's depleted status or that fisheries are the only actions affecting salmon abundance. Rather, it is intended to shed light on the extent to which prey scarcity may be limiting recovery of the whales and the role that salmon fisheries may have in contributing to that scarcity.

By addressing one of the identified threats to killer whale recovery, this process will contribute to the broader recovery programs for Southern Resident killer whales. A rigorous scientific investigation of the effects of fishing on the whales when placed in the broader context of all the factors affecting the whales will better inform future fishery management decisions by NOAA and DFO. Note that this workshop process and the resulting report of the panel are not intended or designed to establish policy or make management recommendations or decisions.

Key question: To what extent are salmon fisheries affecting recovery of Southern Resident killer whales by reducing the abundance of their available prey, and what are the consequences to their survival and recovery?

Overall approach: NOAA and DFO will establish an independent Science Panel to oversee the scientific deliberations and to produce a report at the conclusion of the process. Three workshops will be convened, the first on September 21-23, 2011, the second on March 13-15, 2012, and the third on September 18-20, 2012. The specific objectives of each of the workshops are detailed below. To keep the workshops to a manageable size and foster productive scientific discussion, attendance will be limited to the Science Panel, scientists invited to make presentations ("Presenters") and other experts to engage in the scientific discussions and help perform a scientific peer review function ("Participants"). A limited number of observers representing the public and stakeholders also will be invited, but they generally will not participate in the scientific discussions. All participants in the workshop process are expected to maintain a professional demeanor befitting the scientific nature of the workshop process. Participant selection criteria and the specific roles of the attendees are described below.

Independent Science Panel. The seven-member Science Panel will oversee the workshop proceedings, participate in workshop discussions, question Presenters, critique data and methods, and provide expert feedback on the matters under consideration. By engaging in an iterative dialog with workshop participants, the panel will help fulfill an important purpose of the workshop proceedings: to improve scientific understanding of the subject matter. At the conclusion of the process, the panel will produce a report that:

- identifies the extent to which salmon fisheries in specific locations and times, in combination or in the aggregate, or as a function of annual prey abundance, may be affecting the well-being of Southern Resident Killer Whales by reducing their prey;
- describes the nature of those effects (e.g., through a reduction in whale survival, growth rates, fecundity, or some other mechanism);
- discusses the consequences to survival and recovery of the killer whales; and,
- identifies assumptions, critical uncertainties, and data gaps, their associated implications and research and monitoring actions that would help reduce uncertainties.

Science Chair. Dr. Ray Hilborn, a member of the faculty of the University of Washington, has been selected to chair the independent Science Panel. Dr. Hilborn is a senior scientist widely respected for his scientific credentials, extensive contributions to the scientific literature and professional accomplishments. He was chosen for his expertise and his experience chairing scientific panels of a similar nature. Dr. Hilborn will serve under contract with NOAA and/or DFO.

As Chair, Dr. Hilborn will become familiar with recovery plans, biological opinions, and scientific publications relevant to salmon fisheries and Southern Resident Killer Whales prepared by NOAA, DFO and others as necessary to plan, implement, participate in, and direct the workshop process described herein. He will:

- assist in the selection of the other Science Panel members;
- help frame the agendas and scientific issues to be addressed at the workshops;
- help identify and select appropriate Presenters;
- chair the workshop plenary sessions and work with the Science Facilitator to manage the workshops to ensure objectives for each session are achieved;
- work with the other Science Panel members and the Science Facilitator to identify relevant scientific questions, findings, and uncertainties, provide feedback to Presenters and to summarize results of the proceedings;
- convene intercessional meetings and/or phone conferences as may be necessary to further the purposes of the workshop process; and,
- serve as principal author of the draft and final reports of the workshop proceedings.

Science Panel members (other than the Chair). Six additional scientists (list below) will be chosen for their relevant expertise in salmon fisheries, killer whales and predator-prey dynamics and their ability to constructively and objectively collaborate to fulfill the purposes of the workshop process. Funding for their services will be provided by NOAA and DFO. Panel members will not be employees of NOAA, DFO, any of the agencies involved in managing salmon fisheries in western Canada or the western United States, or entities who benefit economically from salmon fisheries or killer whales (e.g., the whale-watching industry). Although the Panel will include both U.S. and Canadian nationals, no predetermined ratios will be prescribed. The salmon experts will be selected for their knowledge of salmon biology and/or the use, limitations, and assumptions of salmon management models, abundance indices, and other relevant specialties; the whale experts will be selected for their knowledge of marine mammal ecology and/or physiology (particularly killer whales); and the predator-prey experts will be selected for their knowledge of predator-prey dynamics, food webs, and related subjects.

The Science Panel members will become familiar with recovery plans, biological opinions, and scientific publications relevant to salmon fisheries and Southern Resident Killer Whales prepared by NOAA, DFO and others as necessary to prepare for and constructively engage in the workshop process to accomplish its intended purposes. In addition to attending the workshops and participating in the deliberations, Science Panel members will:

- help plan the workshops and identify appropriate preparatory or follow-up steps (e.g., identify additional analysis, pertinent data or methods, appropriate Presenters, etc.);
- critically evaluate the science and data presented at the workshops;
- participate in intercessional meetings and/or phone conferences as may be required to further the purposes of the workshop process;
- formulate findings and help write and review the draft and final reports of the proceedings; and,
- in the event he/she disagrees with findings and conclusions supported by other panel members, write a minority opinion to the report.

Science Facilitator. ESSA Technologies, Ltd., a scientific consulting firm with demonstrated experience in resource management problem-solving processes, has been retained to provide a Science Facilitator (David Marmorek) and other professional staff to provide workshop facilitation services. The Science Facilitator will become familiar with recovery plans, biological opinions, and scientific publications relevant to salmon fisheries and Southern Resident Killer Whales prepared by NOAA, DFO and others as necessary to help plan, implement, and follow through on the workshop process described herein. The Science Facilitator will:

- work with NOAA, DFO and the Science Panel to plan, prepare for and manage the workshops and workshop process;
- assist with logistical matters such as workshop location set-up and distribution of information prepared by Presenters to workshop participants;
- prepare and disseminate materials to facilitate the workshop proceedings (e.g., structured questions, survey forms, etc.);
- maintain detailed records of the proceedings and organize them for inclusion in the final report;
- help organize and participate in intercessional meetings and/or phone conferences as may be required to further the purposes of the workshop process;
- assist the Panel in conducting its analyses and authoring and revising drafts of the report; and,

- assist in the preparation of other documents as may be requested by the Science Panel through the Science Chair.

Presenters. Presenters will include NOAA and DFO scientists who have conducted research relevant to the workshop subject matter and/or conducted relevant analyses in connection with their responsibilities for listed species. Additional Presenters will be experts from outside NOAA and DFO who have been invited to make presentations based on their expertise on matters pertinent to the proceedings. Presenters will attend and participate at their own cost or as supported by their employers or sponsoring entities. In special circumstances, support for travel costs associated with attending the proceedings may be offered to certain Presenters by NOAA and/or DFO if, in the opinion of the Science Chair, they have a particularly important scientific contribution to make to the proceedings and no alternative means of covering such costs is available.

All Presenters will be expected to make their data, analyses and written presentations available at least two weeks in advance of the applicable workshop. NOAA will establish a web site where presentations and other relevant materials, including published literature will be posted and made accessible to participants. At the workshops, Presenters will present summaries of their data, methods, and key findings and participate in the scientific discussions that ensue. In most cases, Presenters will be expected to attend each of the workshops and engage constructively in the workshop deliberations, including serving a role analogous to Participants for presentations made by others.

Participants. A number of additional experts will be invited to attend the workshops and participate in the workshop deliberations. Collectively referred to herein as "Participants," they will be invited based on their subject-matter expertise and their willingness to invest the necessary time to constructively contribute to the workshop proceedings. Some may be experts employed by state, federal, provincial, tribal or First Nations management entities; others may be from non-government organizations or stakeholders groups. Participants will attend and participate at their own cost or as supported by their employers or sponsoring entities.

Participants may bring different data, analyses, views or conclusions to the process, but are not chosen to play an adversarial role with Presenters or any other workshop attendees. Rather, their role is to help critique the scientific data, methods and conclusions, thereby performing a function analogous to scientific peer review. They are expected to come to the process already familiar with recovery plans, biological opinions, relevant scientific publications and the information distributed in advance of the workshops so that they can contribute effectively and constructively to the scientific deliberations. Individual Participants may be requested by the Science Chair to prepare written analysis or documentation of particular points that they may have brought to the deliberations. Participants also may choose to collaborate in the preparation of specific questions or critiques of presentations at the workshops. It also is anticipated that some Participants will prepare papers and make presentations at the second workshop in response to information presented at the first workshop or in response to feedback from the panel after the first workshop.

Public Input. To keep the workshops to a manageable size and to ensure the discussions are focused and productive, attendance at the workshops will be limited to invited attendees. NOAA will establish a web site where presentations and other relevant materials, including published literature will be posted and made accessible to participants and the public. Between the second and third workshops a draft of the scientific panel report will be available for public review and comment.

Workshop 1: September 21-23, 2011 (at a place TBD in Washington State)

Process. The first workshop will take the most time and advance preparation because, as noted above, participants are expected to come to the process familiarized with recovery plans, biological opinions, and scientific publications relevant to the subject matter and as appropriate to the nature of their participation. Presenters will distribute their study results, data and/or analysis in advance of the workshop.

Purposes. Workshop 1 will serve the four primary purposes outlined below. Note that this outline is not meant to serve as the agenda for the workshop and may not reflect the final ordering of topics; a detailed agenda that identifies specific presentation topics and Presenters will be distributed well in advance of the workshop.

1. Establish and discuss the factual context: what do we know about threats to Southern Resident killer whales, their feeding habits, and the relationship between salmon abundance and killer whale population dynamics?
    a. What threats and limiting factors were identified in the recovery plans, and what actions are being taken relative to these findings?
    b. What are the Killer Whale foraging habits and bio-energetic needs: how much food do they need and how/where do they get it?
    c. Census and population structure of SRKW: how many whales are there, of what sex and maturity?
    d. Migratory habits of SRKW: where are they at various times of the year?
    e. Prey species and size selectivity of SRKW: what do they eat?
    f. Food energy value of prey: how many prey items must they eat?
    g. What can we learn from data about the Northern Residents?
    h. What fisheries potentially affect prey availability to SRKW, and to what extent? (Fishery profiles will be provided in advance of workshop.)
    i. What ecosystem considerations and/or trends might be relevant, especially including carrying capacity questions?
    j. What general knowledge can we bring to the problem based on other predator/prey studies?

2. Present and discuss analyses done to date:
    a. Presentations by NOAA scientists: analyses done for consultations on the 2008 PST Agreement and 2011 Puget Sound Resource Management Plan.
    b. Presentations by DFO scientists.
    c. Presentations by states, tribal, First Nations and other scientists on relevant topics as pre-arranged with the Science Chair.

3. Identify and discuss key assumptions and uncertainties and the potentials for reducing them.
    a. Identify additional information and/or alternative methodologies that can be undertaken in the short term (i.e., prior to Workshop 2) to improve confidence in the results and/or otherwise address the questions that were raised.
    b. Identify any other short term or long term research or other ideas that may contribute to reducing uncertainties in the presentations.

4. Identify and assign specific follow-up tasks for completion and presentation at Workshop 2.

Time period between Workshop 1 and Workshop 2.

1. Soon after the first workshop, the Independent Science Panel will meet and deliberate on the presentations and analyses presented at Workshop 1 with a view towards identifying alternative or additional analysis that should occur and/or means by which presented analyses might be improved. This feedback from the panel will be posted on the workshop web site as soon as practicable so as to provide sufficient time for the preparation of refined analyses by Presenters and/or new presentations by Participants for the second workshop.
2. Presenters will refine/modify their analyses based on discussions at Workshop 1 and/or feedback received at or subsequent to Workshop 1.
3. Other scientists may prepare analyses in response to Workshop 1 proceedings for presentation at Workshop 2.
4. Additional information will be compiled for presentation to the workshop process (e.g., biological performance criteria applicable to salmon and marine mammals) and for consideration by the Science Panel.
5. The Science Panel and Facilitator begin to outline the draft report (sans conclusions for matters still under consideration)
6. The Chair and Facilitator prepare and distribute an agenda for Workshop 2.

Workshop 2: March 13-15, 2012 (at a place TBD in British Columbia)

Purposes. The primary purposes of Workshop 2 are as follows:

1. Workshop 1 Presenters will summarize the results of their updated/refined analyses prepared in response to feedback from Workshop 1.
2. Other scientists (e.g., state, tribal, NGO) may make presentations in response to matters presented at Workshop 1.
3. The Science Panel and participants will discuss the new information, ideas and analysis identified in Workshop 2.
4. The Science Panel begins to formulate tentative conclusions and identify key uncertainties in discussions with workshop participants.
5. The Science Panel and Facilitator may meet at the conclusion of the workshop to begin synthesizing the information and assign writing responsibilities for sections of a draft report.

Time period between W2 and W3.

1. The Science Panel members write their assigned sections.
2. The Chair and Facilitator synthesize the sections into a coherent first draft of their report for review by Science Panel.
3. The Science Panel approves its first draft of the report for public distribution.
4. The agencies solicit, receive, and organize (collate and summarize) public comments on the report for consideration at Workshop 3.
5. The Chair and Facilitator prepare and distribute an agenda for W3.

Workshop 3: September 18-20, 2012 (at a place TBD in Washington State)

1. Workshop participants meet to review and discuss:
   a. the scientific findings and conclusions of the Science Panel's draft report;
   b. public comments received on the draft report;
   c. the methods employed to estimate effects of alternative fishery scenarios on prey availability;
   d. major findings and conclusions that can be reached based on workshop proceedings;
2. The Science Panel identifies additional information needed to inform its final report, and how to obtain it.

Following Workshop 3, the Science Chair will collaborate with the Science Panel and the Facilitator to produce the final report by November 30, 2012.

The Independent Science Panel

Dr. Ray Hilborn (Chair), School of Aquatic and Fishery Science, University of Washington

Dr. Sean Cox, School of Resource & Environmental Management – Simon Fraser University

Dr. Frances Gulland, Marine Mammal Commission; Marine Mammal Center, Sausalito, CA

Dr. David Hankin, Department of Fisheries Biology, Humboldt State University, Arcata, CA

Dr. Tom Hobbs, Natural Resource Ecology Lab., Colorado State University, Fort Collins, CO

Dr. Daniel Schindler, School of Aquatic and Fishery Science, University of Washington

Dr. Andrew Trites, Marine Mammal Research Unit, Univ. of British Columbia, Vancouver, BC

Science Facilitator: David Marmorek, President, ESSA Technologies, Vancouver, BC Canada

Review of the Use of FRAM to Obtain Inside/Outside Estimates of Chinook Abundance

As Presented in the May 2011 Biological Opinion

16 September 2011

Angelika Hagen-Breaux

Information Technology Specialist

Planning, Modeling and Verification Unit, Fish Program

Washington Department of Fish and Wildlife

Agree with the following:

- FRAM is likely the best available analytical tool for evaluating the effects of salmon fisheries on Chinook abundance in the "Puget Sound Action Area", but results should be interpreted understanding the challenges associated with using FRAM to obtain regional abundance estimates. In order to increase confidence in the methodology used to estimate inside abundance (the Strait of Juan de Fuca, Georgia Strait, and Puget Sound) some of the major assumptions made to estimate regional abundance need further evaluation.

Background Information

FRAM is a single-pool model, where all fisheries occurring in the same time step operate on the entire time step abundance of a stock. FRAM uses stock specific exploitation rates by fishery, age, and time step to compute and evaluate fishing impacts. FRAM provides yearly ocean abundance estimates, but does not produce estimates of the abundance available to a fishery and does not contain information about the distribution of stocks.

Base period annual exploitation and escapement rates by stock and fishery were used to allocate abundance to inside waters and coastal waters. Therefore, every stock had percentage contribution to inside waters and coastal waters within the range of SRKWs and percentage outside the range for SRKWs (SEAK and part of northern BC) adding up to 100%. Base period rates were used, because the base period (early 80s) had relatively few fishing restrictions. Fisheries were open over large geographic and time strata. Catches and escapements were assigned to Inland versus Coastal areas using the following rules:

- Inland Chinook—Chinook caught in inland waters (Geo St, JDF, PS, HC) and Chinook escapement of all stocks with origin in Inland waters and expected to pass through. Includes portion of non-inland origin Chinook stocks intercepted in inland waters (e.g. Col Tule caught in JDF)
- Coastal Chinook (Outside)—Chinook caught in coastal waters for SRKWs (excludes SEAK and part of northern BC) and Chinook escapement of all stocks with origin in outside waters.

For each stock these proportions were applied to the age and time step abundance after natural mortality and after pre-terminal fisheries. These abundances were derived from FRAM's "Popstat" report.

Missing Pieces

- It would be helpful if more information about the "Mortality and Escapement Distribution Report" were included; e.g. was the report using landed catches, total mortality, or total AEQ mortality. While none of these mortality types would produce accurate estimates of the distribution of non-landed encounters, the total mortality report would at least account for the release mortality to non-landed Chinook.

Criticisms/Suggested Improvements

- While FRAM is a recognized tool for evaluating the impacts of fisheries on Chinook stocks, it has not been designed to make estimates of regional abundance. Using the model in that manner requires the postulation of several major assumptions which are in need of being validated.

  - Base Period exploitation rates are a good indicator of regional abundance. If this assumption is accurate, then it would be more appropriate to allocate inside/outside abundance without regard to escapement. If the base period exploitation rate truly captures availability over space and time, where a stock escapes should be irrelevant, since SRKWs cannot access escapement. Including escapement in the allocation equation would then lead to overestimating the contribution of Puget Sound and other "Inside" stocks to Inland waters.

  - The inside/outside distribution of each stock remains relatively stable from year to year.

  - Each stock has a similar inside/outside distribution for all ages and time steps.

  If latter assumption is violated, estimates might be improved by using FRAM's time step and age specific base period exploitation rates, rather than computing the base period rates over all ages and time steps for each stock.

- In FRAM, the abundance (after natural mortality and after pre-terminal fishing) is very sensitive to FRAM's maturation rates. FRAM usually starts with a terminal run size forecast by stock and age. This forecast is then expanded using average pre-terminal exploitation, natural mortality, and maturation rates. Fish that do not mature, will not escape in the fishing year being evaluated and will be subject to natural and fishing related mortalities in subsequent years. Due to this effect, a pre-terminal fishing mortality rarely translate into an equivalent loss of escapement; e.g. one more fish caught usually produces less than one fewer fish escaping. Because abundance estimates for younger fish are so sensitive to this parameter, its effect on abundance estimates as well as the assumption that mature and immature fish of the same age are similarly distributed should be carefully evaluated.

Review of the Effects of Chinook abundance on SRKW Fecundity, Survival, and Population Growth
As Presented in the May 2011 Draft Biological Opinion

16 September 2011

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The Biological Opinion (BiOp) presented analysis relating Chinook abundance to Southern Resident Killer Whale (SRKW) fecundity (e.g., from Ward et al. 2009 and Ward 2010), and there is an implicit assumption in the BiOp that a decrease in Chinook abundance will lead to a decrease in SRKW fecundity. I agree that this is a reasonable position; regardless of the measurement of Chinook abundance (e.g., FRAM, WCVI), there is convincing evidence that fecundity of SRKWs is positively correlated with Chinook abundance.

Furthermore, I believe that there is sufficient evidence (i.e., Ford et al. 2005, Ford et al. 2010, Ward 2010) to conclude that it is more likely than not that SRKW survival is also positively correlated with Chinook abundance.

The combination of evidence suggesting increased fecundity and increased survival with increased Chinook abundance provides sufficient evidence of a link between Chinook abundance and SRKW population growth rates. Although the evidence linking Chinook abundance to increased SRKW population growth rates (through survival and fecundity) is correlational and not causational, there is sufficient biological mechanisms and data on diet to conclude that it is probable that a decrease in available Chinook will lead to a decrease in SRKW growth rates (all else being equal).

It is my opinion that focusing on the effect of management strategies (e.g., fisheries) on SRKW population growth rates is the most informative metric as it offers tangible and objective thresholds (i.e., Is the population growth rate positive or negative? Is it obtaining the recovery level of 2.3%?) and is, therefore, preferable to using the ratio of kilocalories available-to-needs, which lacks an objective threshold (other than the minimal and clearly sub-sufficient level of 1:1).

However, there are a number of ways that the projection of population growth relative to Chinook abundance could be substantially improved. The key points being:

- The analysis should be stochastic and individual-based, not deterministic (based on expected-values thus allowing for fractional animals).

- It would be particularly useful to stochastically project the population out to 28 years because the recovery goal specifies an average annual growth rate of 2.3% over 28 years. It would be of direct and explicit value to have a measure of the probability of (what percent of simulations had)
    - the population meeting the recovery goal under various scenarios.
    - positive population growth rates

I then list a number of key details that were omitted (not available to us), that would be needed to fully understand and evaluate the analysis presented in the BiOp.

<u>Suggestions for Improvements</u>

In Ward 2010 (and used in the BiOp), confidence intervals are given for *R* and for the estimated population change over 10 years. While Ward 2010 did account for 3 forms of uncertainty (model selection, parameter estimates, and sex ratio at birth), I feel that the most critical component of variation was omitted, namely the demographic stochasticity that derives from very small population sizes. One additional or one fewer birth or death would have a greater impact on *R* than all 3 of the sources of uncertainty allowed for in this analysis. Below I detail a number suggestions for improvements to this analysis.

My understanding (based, somewhat on assumption) of how the confidence intervals for *R* were obtained is as follows.

(1) Bootstrapping was used to sub-sample the data to obtain a range of parameter values for each of the top 4 fecundity models and for the survival model (accounting for uncertainty in parameter estimates).

(2) For each bootstrapped data set, the 4 resulting fecundity models were model-averaged (accounting for uncertainty in model selection).

(3) The proportion of female births was drawn from a Normal $\left(\mu = 0.54, \sigma = \sqrt{\frac{(0.54)(1-0.54)}{89}}\right)$ distribution (accounting for uncertainty in sex-ratio at birth).

(4) From the results of steps (1) through (3) above, a *single* value of *R* was calculated for a given FRAM Chinook abundance.

(5) Steps (1) through (4) were repeated 1,000 times each, for each level of FRAM Chinook abundance, for the following levels of FRAM Chinook abundance: {0.60, 0.65, 0.70, . . . , 1.80}. Thus, a mean and 95% confidence interval were obtained for *R* for each level of FRAM Chinook.

(6) An equation relating *R* to FRAM Chinook abundance was calculated using Simple Linear Regression of the mean *R* at each level of FRAM Chinook from step (5) versus FRAM Chinook, resulting in the growth equations for J/K and L pods on p. 109 of the BiOp.

(7) The 10-year population projection (estimated change in population size) was estimated by *deterministically*, applying each R from step (4) to the population: $\left[N_{0,J/K}(1+R_{J/K})^{10}+N_{0,L}(1+R_{L})^{10}\right]-\left(N_{0,J/K}+N_{0,L}\right)$. Where N_0 denotes the initial population size and the subscript J/K and L denote the pod(s).

It is the *deterministic* application of R in population projections and further analysis that I take issue with. I believe a *stochastic* approach, allowing for demographic uncertainty would be far more appropriate for a population of such small size and comprised of such long-lived members as the SRKW population.

A more appropriate *stochastically-based* analysis might be as follows.

- For each member of the population and using actual SRKW population age and gender structure, apply a random number generator to determine whether the individual survives and reproduces based on the probabilities predicted by the survival and fecundity models. If the individual reproduces, use a random number generator to predict whether the offspring is male or female.
  - While, I do not believe it would be required to add in the additional sources of uncertainty as in Ward 2010, I would not object to also adding in those sources of uncertainty. I suggest the following ways that additional sources of uncertainty may be added.
    - Bootstrapping to obtain a range of model parameter estimates as was done in Ward 2010.
    - Drawing the parameter estimates from a distribution, *e.g.*,
      - the normal distribution with mean equal to the observed point estimate of each parameter and standard deviation equal to the standard error of that parameter
      - a uniform distribution over the range observed in the last several years (*e.g.*, 1994-2008) or slightly wider
      - A distribution skewed towards the lower end of the observed range, if, perhaps, Chinook numbers are expected to decline over the time period of interest.
    - To incorporate uncertainties in sex ratios at birth, simply assume a probability of female of 0.54 (48/89, the observed proportion of female calves) or 0.50 (the observed proportion of females, 48/89, is not significantly different from 0.50, 2-tailed exact test: p = 0.5250). It would also be reasonable to follow the concept used in Ward 2010 and draw the probability of female from the Normal$\left(\mu=0.54,\sigma=\sqrt{\frac{(0.54)(1-0.54)}{89}}\right)$, which would allow for over-dispersion from the binomial. Regardless of the approach above to determine

the *probability* of being born female, a random number generator should be used to determine if each calf will be simulated as a male or female.

- Other modifications to consider include:
  - Holding the fecundity to zero if/when the number of mature males is 0.
  - Forcing a gap in reproduction for females, for example precluding females that reproduced in one year from reproducing in 1 or more subsequent years; or using the observed calving interval from Olesiuk et al. 2005, Figure 11, or similar data, if available, from the Southern Resident population. However, appropriate calving intervals will likely be a natural consequence of low annual probabilities of calving and may not need to be explicitly modeled.

- Instead of assuming a constant Chinook abundance, allow Chinook numbers to vary following observed data. This could be done by:
  - randomly drawing (i.e., with equal probability) from the observed values over 1984-2008 (or another reasonable time period)
  - drawing the Chinook abundance from a Normal distribution with mean = 1,387,216 and standard deviation = 263,906 (this is the observed mean and standard deviation for 1984-2008, based on the BiOp, Appendix Table 1, p. 202).
    - Run out the population for a set period of time (e.g., 3 years as in the BiOp, 10 years as in Ward 2010, or 100 years as in the PVA), allowing variation in the annual Chinook abundance each year. ***I suggest that projecting the population out to 28 years might be of value because the recovery goal specifies an average annual growth rate of 2.3% over 28 years.***
    - Calculate *R* (or lambda) from the observed change in population size (instead of calculating population size from projecting *R* deterministically). ***It would be of direct and explicit value to have a measure of the probability of (what percent of simulations had) the population meeting the recovery goal under various scenarios.***

- Based on Ward 2010, the BiOp (p. 110) also gives a range for the estimated percent reduction in the SRKW population over 3 years of 0.2 to 0.6 of a whale, an interval that is clearly impossible and, thus, has an unrealistic level of precision. In calculating the potential impact of the proposed fishing (e.g., BiOp, Appendix 1, Table 1, p. 202), using the 2006 Chinook abundance (1,870,628) for illustration, the predicted 3-year population change under no action would be: $[45(1.029)^3 + 41(1.029)^3] – (45+41) = 7.701$; and with a 6.6% reduction would be: $45(1.026)^3 + 41(1.027)^3] – (45+41) = 7.014$, a difference of roughly 0.7 of a whale. Clearly this is an unrealistic prediction. Focusing on J/K pods (for simplicity) the no action population change would be $45(1.029)^3 – 45 = 4.0296$. However, that is not a possible outcome. You can have a change of 3, 4, or 5 whales, but not any value in between. A change in 3, 4, or 5 whales over 3 years would translate into *R* of 1.022, 1.029, and 1.036 respectively. Thus demographic stochasticity seems to far outweigh the difference caused by the proposed action (1.029 vs. 1.022 for one fewer whale compared to 1.029 vs. 1.026 for the proposed action). I suggest the following as an improved measure of the impact of various fisheries scenarios.

- Stochastically model the population as described above, but in addition to allowing the abundance of Chinook to vary randomly over the simulation time-period, also allow the percent reduction due to the proposed action(s) to vary, for example drawing the percent reduction from a normal distribution with a mean of 3.8 and a standard deviation of 1.0 (the observed mean and standard deviation from the BiOp Table 21, p. 110).
- ***The following metrics would be useful and informative summaries***
  - ***Give a distribution of R (based on the stochastically generated population change), and, in particular note what percent of the simulations had R below the recovery goal of 2.3%.***
  - ***A probability mass function of the observed change. Essentially, what percent of simulations had a net change of {. . ., -1, 0, +1, +2, . . . } whales.***

<u>Missing Pieces</u>

The following are key details that would be required to fully understand and evaluate the analysis presented in the BiOp.

- Parameter estimates (as well as standard error or confidence intervals) for models used to generate estimates of *R* (the four top fecundity model and the survival model in Ward 2010)
- In Ward et al. 2009, data from both the Northern and Southern Residents were used (some models allowing for a constant effect of Region). In the 4-page write-up of Ward 2010 that I was able to review as well as in the BiOp where this analysis is discussed, it is not clear whether data from both Northern and Southern residents were used to build and select the models or if only data from the southern residents were used.
- It is not entirely clear what the *x*-axis (independent variable) is. In Ward 2010, the *x*-axis for each figure is labeled “FRAM Chinook abundance (millions)”, suggesting this is actual numbers of fish. However, in the BiOp, Figure 8 shows the same plot (or very similar) with the same equation, but the x-axes are labeled “FRAM Chinook abundance (proportion relative to 1984-2008 mean, 1.4 million)”, so it is unclear whether the mean/typical abundance is 1.4 or 1.0 on the scale given. Furthermore, there are places in the BiOp (e.g., Appendix 1, Tables 3-6) where the Chinook abundance is labeled “No Action FRAM Chinook Abundance 3-5 yr-olds Jul-Sept.” These numbers match those presented elsewhere in the BiOp as simply “Chinook Abundance.” My concern is solely whether the data used to build the models and estimates was the same as that being used in the inference interpretation, whether that was only 3-5 yr-old FRAM Chinook or whether it was *all age* FRAM Chinook. And finally, the time period of 1984-2008 is

given as a reference (and the index is relative to the average over that period), but elsewhere in the BiOp where Chinook abundances and reductions due to fisheries are presented, the time range is 1994-2008, not 1984-2008 (e.g., Tables 13, 15, 16, 19, 20, 21, 24, 25, 26, 27, and the Tables in Appendix 1)

- The growth equations for J/K and L pods given in the BiOp (page 109) are cited as coming from Ward 2010. However, these equations are not given in the 4-page document available as Ward 2010, and I believe further detail on their derivation would be appropriate. I am assuming that these equations are obtained via simple linear regression on the point estimates of R for each level of FRAM Chinook {0.60, 0.65, . .. 1.8}, but this is not explicit. In addition, estimated population growth in Ward 2010, was given using the 2009 age-structure *and* assuming a stable-age distribution. It is not clear which scenario these equations are based on (assuming either). For reference, those equations were:

  J/K pods: 0.0250*(% FRAM Chinook abundance, relative to the 1984-2008 mean) – 0.0050

  L pod: 0.0242*(% FRAM Chinook abundance, relative to the 1984-2008 mean) – 0.0035

<u>Literature Cited</u>

Ford, John K. B., Graeme M. Ellis, Peter F. Olesiuk. 2005. Linking prey and population dynamics: did food limitation cause recent declines of ‘resident’ killer whales (*Orcinus orca*) in British Columbia? DFO Canadian Science Advisory Secretariat Research Document 2005/042.

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Olesiuk, Peter F., Graeme M. Ellis, and John K.B. Ford. 2005. Life history and population dynamics of Northern Resident Killer Whales (*Orcinus orca*) in British Columbia. DFO Canadian Science Advisory Secretariat Research Document 2005/045.

Ward, Eric J., Elizabeth E. Holmes, and Ken C. Balcomb. 2009. Quantifying the effects of prey abundance on killer whale reproduction. Journal of Applied Ecology 46: 632-640.

Ward 2010 unpublished “New Demographic Model”, a 4-page document

Review of Southern Resident Killer Whale Diet Selectivity, Metabolic and Calorie Needs, and Ratio of Prey Availability to Killer Whale Needs As Presented in the May 2011 Draft Biological Opinion

3 October 2011

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Prey availability compared to SRKW needs

Suggestions

The authors assess the ratio of Chinook energy available to SRKW energy needs in the Salish Sea. They also look at these ratios for other marine predators. Based on these assessments, they suggest that the ratios for SRKW are low and that SRKW populations may be adversely effected by low abundance of Chinook prey. Unfortunately, there is no independent objective threshold to determine if the ratio is low, adequate, or high based on the information presented. Instead of this approach, I recommend using the FRAM Chinook abundance as an index of abundance and relate that index to population growth. If, for example, the goal is to determine the amount of Chinook needed to reach recovery of SRKW, I recommend determining a threshold of FRAM Chinook abundance that will achieve the recovery objectives for the SRKW (2.3% annual growth over 28 years). This threshold can be identified by using Ward's (2010) predicted relationship between SRKW annual population growth rate (R) and abundance of Chinook in the inland waters between July and Sept (but after addressing the recommendations from Shannon Knapp). With this approach, it is no longer necessary to try to calculate the calories available to SRKW which is very difficult task given the data on-hand.

Species and size selectivity by SRKW

I agree with the following

- The conclusion that SRKW select Chinook disproportionately in their summer range (May through Sept.) is convincing given the available information from Hanson et al. 2010 and Ford and Ellis 2006. The SRKW diet samples (n = 309 from Hanson et al. 2010 and n = 46 from Ford and Ellis 2006) come from locations that appear to represent most of the areas used by foraging SRKW during the May-September period in the study areas of Puget Sound, Strait of Juan de Fuca and on the west coast of Vancouver Island.

In both studies > 82% of the samples were identified as Chinook and no other species or species group (e.g., "other" or "unidentified salmon") represented more than 7% of the samples for SRKW. The vast majority of the diet samples came from Frasier River stocks with minor components from north and south Puget Sound and with some variability by diet sample collection locality and month. Samples represent many years (Pink and non-Pink years) between 1975 and 2008. There was generally good agreement between sample type (e.g., scale and tissue and fecal). The data seem to be representative of the SRKW diet while in the study areas of Puget Sound, Strait of Juan de Fuca and on the west coast of Vancouver Island (especially in Hanson et al. 2010). However, there are times (they can be considerable proportions of some months) when SRKW are likely not in these areas and, as a result, the diet as represented by the samples in Hanson et al. 2010 may not be representative of SRKW diet in areas outside the Salish Sea and west coast of Vancouver Island. The diet in "other" locations may be captured in Ford and Ellis 2006 but locations of samples by pod are not provided. To address this issue, the authors account for the number of days spent in the inland waters (using data from Hanson and Emmons 2010) when assessing the whales energy needs from Chinook for this region and time period.

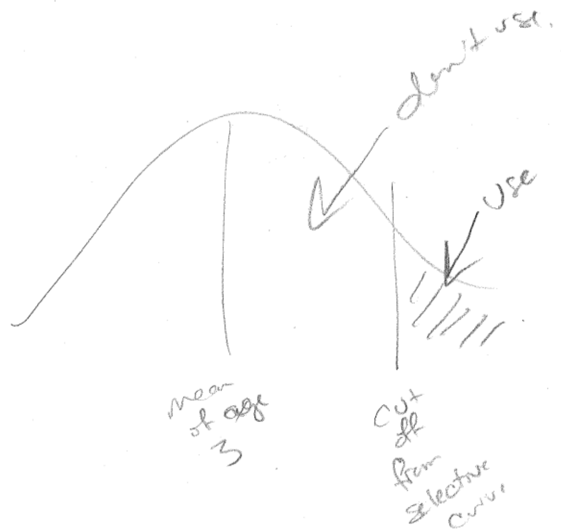
- The conclusion that SRKW select older and larger Chinook in their summer range is supported by the information in Ford and Ellis 2006 (see Table 5 and Figure 2) but the analysis in the Biological Opinion relies on unpublished data that are not presented.

Missing Pieces

- Would like to see the unpublished data describing age distribution of Chinook samples presented (page 80) - ideally by pod, date and location.
- When assessing the availability of Chinook by age in Puget Sound, Ward et al. (2010 unpublished) used three sources as estimates of availability (FRAM, PSC, and CWT) but selected FRAM – why was FRAM selected? Is it because FRAM predicts decreasing abundance with age? – Which seems reasonable.
- The selectivity curve is used to select fish available to SRKW. Did the authors select available Chinook from FRAM in proportion to SRKW selectivity (the Function presented) or did they select some threshold above which the Chinook were included in the availability analysis as available. If the latter, what was the threshold value and why was it selected?

Suggestions

When converting age-based selectivity parameters to length parameters, I recommend using the distribution of lengths for each Chinook age class rather than using the means (can coded wire tag data be used for this purpose?). This approach, in the end, is more likely to represent the calories available to SRKW. For example, if 20% of age 3 fish are expected to be greater than the selectivity threshold based on length, then 20% of age 3 fish could/should be included in the calculation of kilocalories available to the SRKWs



A hypothetical distribution of age 3 fish sizes is drawn above with a hypothetical size cut off from the selectivity function. I am recommending that you use this type of approach and use the proportion above the selectivity threshold for each fish age class to determine the fish available to SRKW.

Estimating SRKW metabolic rates and calorie needs

I agree with the following

- The use of Noren et al. 2011 seems appropriate for estimating metabolic requirements of SRKW.

Missing Pieces

- I cannot evaluate the appropriate residence time in coastal areas without seeing the unpublished Hanson and Emmons data or some analysis of the data.

Suggestions

- Would it make sense to update the metabolic analyses using actual size and growth trend data for SRKW from Fearnbach et al. (2011)?